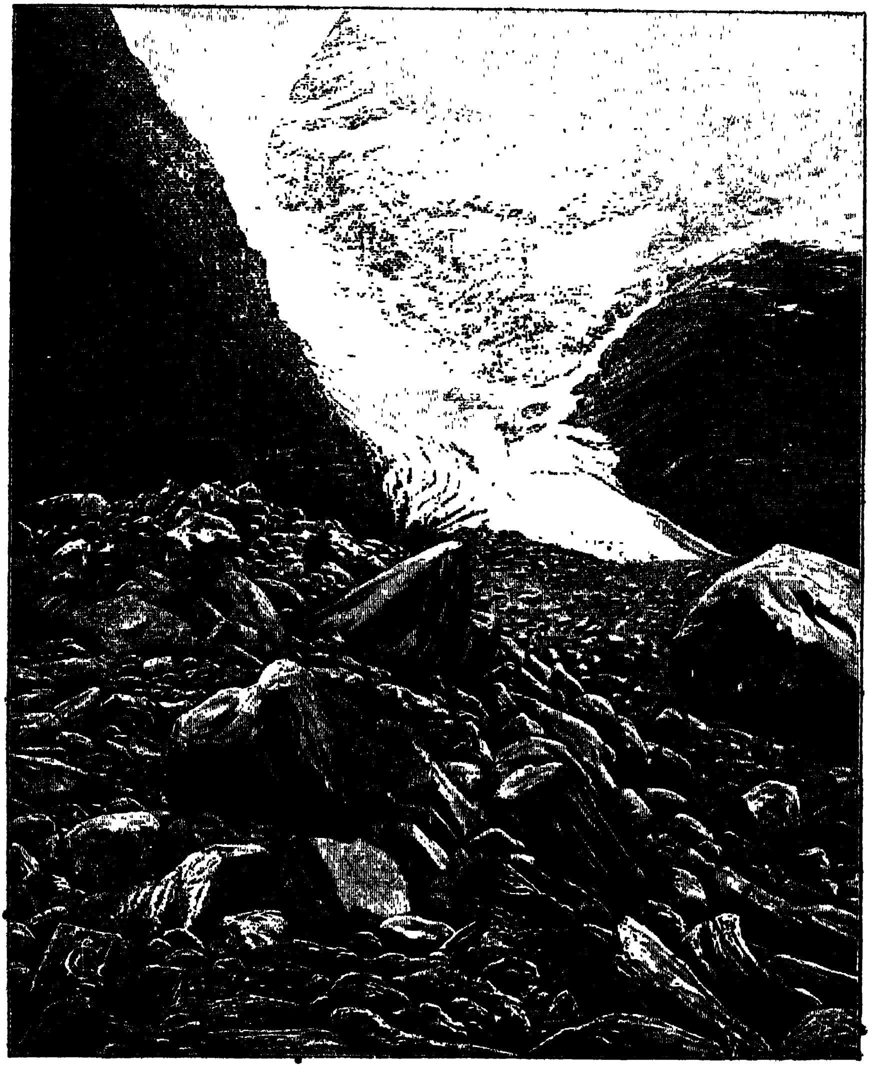

THE MAHAPANTH.

Glacier of Kedarnath.

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XXIII.

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MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

GEOLOGY *of the* CENTRAL HIMÁLAYAS, *by* C. L. GRIESBACH, C.I.E., *Superintendent, Geological Survey of India.*

PART I.

PHYSICAL AND STRATIGRAPHICAL FEATURES.

CHAPTER I.—INTRODUCTION.

Area.

The ground which is described in the present volume may be roughly defined as lying between the 78th and 81st degrees of longitude, or between the Spiti valley and the frontier of Nepal, and forms a narrow strip of sedimentary rocks north of the chain of high peaks in the Central Himálayas.

During my journeys to and fro to the regions of eternal snow, I crossed the entire breadth of both outer and higher Himálayas within the area above mentioned; in the present memoir, however, I have limited my descriptions almost entirely to the belt of sedimentary rocks, which form, as it were, a high rim round the southern edge of the great Húndés high-plateau.

The area under description comprises the Bhót-mahâls of Kumaún, Garhwál, and of Tihri Garhwál; the adjoining portions of the province Gnari-Korsum (Húndés) of Tibet, the watershed between that country and Bisahir and south-eastern Spiti.

Maps.

The accompanying two maps show the extent of the area reported on, but as no reliable topographical maps of Húndés have been published, I had to omit part

of that ground. Nevertheless I describe the geological features of those parts in my text, and the figured sections, as far as I am able to do so.

The map No. 1 has been reduced to the quarter-inch scale from the large scale maps of the Survey of India, 1 mile = 1 inch, and consequently the geological boundary lines will be found to be in much greater detail than could be attained in surveying the Spiti ground, of which only the old Indian Atlas sheets were available. The boundary lines there had to be put in more or less diagramatically only.

Delay in publication.

I began surveying work in the Niti area in 1879, and continued my explorations amongst the snows during intervals, when I was not engaged in travelling on the North-West Frontier or in Áfghánistán. My repeated expeditions to the latter country have delayed the publication of this memoir for a much longer period than I ever anticipated. The delay, however, has enabled me to add explorations in the Hindu Kúsh and Khorassán to my experiences, and so has made it possible for me to compare the structure of the great Himálayas direct with that of regions which stand in more or less structural connection with the former.

Literature.

The number of previous writers on subjects, either purely geological or related to the geology of the Central Himálayas, is very great, but very few of their papers afford real help in unravelling the complicated structure of the ground.

The following is an alphabetical list of the authors who have dealt with subjects more or less connected with the geology of the Central Himálayas or adjoining regions. In this list I have left out all papers dealing with the outer Himálayas and the Siwaliks, excepting one or two authors on the latter areas, who happen to express theories applicable to the Himálayas generally. I also included papers, such as Lydekker's Kashmir, which although not immediately relating to the ground described in this memoir, yet has a close bearing on questions which affect the geology of the Central Himálayas.

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107. ——— Geological notes on the route traversed by the Yárkand Embassy from Sháh-i-dula to Yárkand and Káshgar. Rec. Geol. Surv. Ind., VII, 49—51, 1874. Quart. Jour. Geol. Soc., XXX, 571—575, 1874; T. D. Forsyth's report, etc., 462—464; Yárkand No. 1, 21—23.

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120. ——— On the geology of part of the Himalaya mountains and Thibet. Quart. Jour. Geol. Soc., VII, 292—310, 1851; Brit. Ass. Rep., 1857, pt. II, p. 69.

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All the papers recorded in this list of literature contain mention, more or less extensive, of the rocks and minerals found in the Central Himálayas or adjoining regions, but practically only the following authors need be considered here :—

1851. Strachey, R.—On the geology of part of the Himálaya mountains and Thibet.—Quart. Jour. Geol. Soc., VII, 292—310.

General Strachey gives, in this short paper, the results of many years of study in the Central Himálayas and the adjoining province of Húndés; with the map it forms by far the most important contribution to our knowledge of the geology of the Himálayas. He distinguishes correctly, in the main, the various systems which he met north of the great gneissic axis, although all detail is avoided. In descending order he distinguishes—

7 Tertiary deposits of Húndés.
6 Grits, shales and limestone.
5 Shales (Oxford, Spiti shales).
4 Jurassic series (limestone, etc.).
3 Trias.
2 Palæozoics.
1 Azoic slates.

Soon after the publication of this paper, notes and descriptions of

fossils collected by General Strachey and by others appeared. Amongst them I mention—

1862. Suess, E.—Letter on triassic fossils collected by General Strachey in the Verh. Geol. R. Anstalt, 1862, Vol. XII, p. 258, who recognized true Alpine trias *Ammonites* amongst those collected in the Niti area.

1863. Blanford, H. F.—On Dr. Gerard's collection of fossils from the Spiti valley in the Asiatic Society's Museum. Jour. As. Soc. Beng., XXXII, 124—138.

In this paper Mr. Blanford describes chiefly forms found in the Spiti shales, but there are several fossils amongst them both older and younger than the jurassic Spiti shales.

1863. Oppel, Dr. A.—Über ostindische Fossilreste aus den secundären Ablagerungen von Spiti. Pal. Mitth. 1863, 267—302.

This paper is a most important contribution to the palæontology of the Himálayas; although it mostly describes Spiti shale fossils, there are amongst the figured specimens several which are evidently of lower trias age, certain of them very characteristic of the Himálayan trias fauna.

1864. Beyrich, E.—Über einige Trias Ammoniten aus Asien Monatsb. Akad. Berlin, 1864, 59—70.

1866. " —Über einige Cephalopoden aus dem Muschelkalke der Alpen and über verwandte Arten. Abh. Akad. Berlin, 1866, 105—150.

In these two papers Prof. Beyrich describes important triassic forms, collected by the brothers Schlagintweit in the Himálayas, and he discusses their relationship to Alpine forms.

1865. Gümbel, C. W.—Über das Vorkommen von unteren Trias-Schichten in Hochasien. Sitz. Ber. Akad. Wiss. Munich 1865, II, 348—366.

The author recognizes genuine lower trias fossils amongst the collections brought by the Schlagintweit brothers.

1865. Blanford, H. F., and Salter, J. W.—Palæontology of Niti in the Northern Himálayas, 8° Calc., 1865.

This publication completes, as it were, the researches of General Strachey; it contains description and figures of the fossil remains found by the latter in the Niti area. Up to the present it is the only full account of the palæontology of the Himálayas.

1865. Stoliczka, Dr. F.—Geological sections across the Himálayan mountains from Wangtu bridge on the river Sutlej to Sungdo on the Indus, etc. Mem. Geol. Surv. Ind., V, pt. I, 1—54 (1865).

This memoir may perhaps be looked upon as the most important amongst the Himálayan writings, since the views expressed by Dr. Stoliczka have found extensive application by most of the later authors on Himálayan geology. Subsequently to the publication of this, Dr. Stoliczka wrote a number of papers (see list) on various geological sections in the North-Western Himálayas and Tibet; in all of them he adopted the classification set forth in the above paper. Had he ever been able to re-visit Spiti and carefully survey the ground, he would no doubt have entirely modified his views, which, I found, were not always correct. I give here his list of formations.

In descending order he distinguishes :—

Chikkim shales and limestone	Upper Cretaceous.
Gieumal sandstone	Upper Jurassic?
Spiti shales	Middle Jurassic?
Earthy shales	Jurassic.
Upper Tagling limestone	Lias.
Lower do. do.	Lias.
Para limestone	Rhaetic.
Lilang series	Upper Trias.
Kuling series	Carboniferous
Muth series	Upper Silurian.
Babeh do.	Lower Silurian.

The above classification was adopted by Lydekker in his work on Kashmir, and also by the authors of the Manual of the Geology of India. I also tried at first to identify the strata, as I found them in the Niti area with the descriptions given by Stoliczka from the Spiti ground, but entirely failed. In the Niti area, and other sections of the Central Himálayas, the sequence differed entirely from that given by Stoliczka, and I could do nothing else but either give

various local names to the systems, or adopt the European nomenclature for them. This I found easiest, as all or nearly all the strata yielded good fossils, many of which stand in close relationship to European forms.

Long before I had an opportunity of studying the Spiti sections myself, I believed that I would find the succession of strata in that valley much the same as in the Niti sections, and this I found to be the case. I shall have again occasion to refer to this subject when discussing the Spiti sections, and may here content myself with stating in few words how much I differ from Stoliczka.

(1). His Babeh series is only partly lower silurian ; the greater part belongs to the underlying strata, which I have termed the Háimanta system. (2). The Muth series is almost entirely carboniferous, and the succession of beds from the Babeh to the uppermost Muth series is not as stated in Stoliczka's memoir. (3). The Kuling series is only partly carboniferous ; under this name are comprised not only the dark *Productus* shales, but also some portion of the lowest triassic beds, which yield a good many fossils near Kuling. (4). The lower trias is represented and is in strong force in the Spiti valley. (5). The lower Tagling limestone is only partly lias, the greater thickness belongs to the *Lithodendron* limestone of the rhaetics.

These are the principal points on which I differ from Stoliczka, and having found that his nomenclature was based to a certain extent on hasty and incorrect observations, it would have been misleading to apply the same to rocks in other areas.

1868. Medlicott, H. B.—The Alps and the Himálayas. Quart. Jour., Geol. Soc., Lond., XXIII, 322; XXIV, 34—52.

1882. The Geology of Kumaon and Garhwal. Gazetteer of the North-Western Provinces of India, Vol. X, 111—168.

Both these papers are very important to the student of Central Himálayan geology. In the first paper the author speculates on the probable cause of the great flexures into which mountain chains, in particular those of the Alps and Himálayas, are laid, aud comes

to the conclusion that we must rather look to subsidence than "upheaval" as the primary cause of this folding process. In his second paper the author has compiled all the knowledge we possess of the geological structure of the Kumaon and Garhwal Himálayas It is chiefly a summary of the author's own work in the Lower Himálayas and Siwaliks, and a reprint of General Strachey's paper above quoted, and forms an exceedingly important addition to the Himálayan literature.

1880. Griesbach, C. L.—Geological notes. Rec., Geol. Surv., Ind , XIII, 83—93. (1880).

1880. Palæontological notes. *Ib.* 94—113.

In these papers I have given preliminary notes on my first season's work in the Himálayas, which will be found in greater detail in the pages of this memoir.

1887. Oldham, R. D.—Notes on some points of Himálayan Geology. Rec., Geol. Surv., Ind , XX, 155—161.

1888. The sequence and correlation of the pre-tertiary sedimentary formations of the Simla region, etc. *Ib.*, XXI, 130—143.

1888. Some notes on the geology of the North-Western Himálayas, XXI, 149—159.

Mr. Oldham touches upon some points closely connected with the structure of the Central Himálayas besides giving his views on the Spiti section. The latter are founded on insufficient data, which I have shown in a paper,

1889. Geological notes. Rec., Geol. Surv., Ind., XXII, 158—167 (1889), to be to some extent untenable. In the chapter on the Spiti sections I shall again refer to these differences.

The papers by Colonel McMahon and the later ones by Mr. Middlemiss, although of great importance generally, and especially so as regards Himálayan geology, do not directly deal with ground described in this memoir, and I therefore need not do more than refer the reader to the foregoing list of authors.

CHAPTER II.—PHYSICAL FEATURES.

If it were possible for us to obtain a bird's-eye view of the highlands of Central Asia, then we should see a high table-land surrounded by a rim, which latter consists of a system of parallel ranges, in which are situated some of the most gigantic mountains of the world.

This is the Tibetan plateau with its fringing rims of the Himálayas and the Kuenlun ranges. On the high table-lands of this region we find the headwaters of several great rivers, which, flowing through gaps in the hill barrier, skirt it along its southern sides and empty themselves into the plains of India, after traversing the entire width of the mountain belt of the Himálayas.

The geologist, however, sees in the mighty ranges which not only fringe this high plateau, but also traverse it in more than one line, the result of an extensive wrinkling and folding process, which has taken place all over the present continent of Asia, and which caused long lines of gigantic flexures to form, many of them reversed and often pushed one over the other along lines of dislocations,—folds which by degrees lifted the great thicknesses of the palæozoic, mesozoic, and even tertiary deposits to the stupendous altitudes in which we at present find them.

Between these lines of flexures the later tertiary and recent deposits have been laid down in horizontal deposits, thus assisting to form the great table-lands of Tibet and the Gobi. Amongst the highest of these plateaux is that part of Tibet called Gnari-Korsum, or by the Indians, Húndés (land of the Húns). Wide-spread, horizontal beds of younger tertiaries nearly fill the basin-shaped synclinals between the systems of flexures. The latter form the fringing "rim" to which I likened the great parallel ranges of the Himálayas.

The lowest portion of the elevated plateau of Húndés reaches a mean sea level of about 12,000 to 16,000 feet, and is generally a bare, bleak plain, in which the Sutlej with its side drainage has eroded deep gorges, so charac-

Húndés plateau.

teristic for the greater part of Central Asia. It is bounded on the south by the great ranges of the Himálayas, and in particular by the range of sedimentary rocks which forms the watershed between the upper drainage of the Sutlej and the Ganges. The strike of these ranges coincides generally with the direction of the great flexures of the Himálayas, namely, from south-east to north-west.

In Pl. 12 I have given a view of the Húndés plain as seen from near Dongpú nearly in the centre of the valley. As will be observed, the Húndés province is not, properly speaking, a plateau; in fact the enclosing rim, which consists of the Himálayan ranges and the "Kailas" chain, rather defines it as a basin highly elevated above the surrounding parts of Central Asia. When travelling northwards from India to Tibet, through the deep valleys and over the great passes of the Himálayas, the eye becomes so accustomed to stupendous mountain masses, and a seemingly interminable succession of ranges and steep cliffs, that when finally reaching the last crest of the watershed, the view over the Húndés basin, which meets the eye, fairly takes one by surprise. At one's feet stretches, as far as the eye can see, an apparently level expanse of country, a level in which at that distance all lower ridges and inequalities seem to disappear. All of it is more or less of a brownish green colour—bare patches of gravelly soil with streaks of bright green pasturage. Not a soul, nor living creature apparently inhabits this immense waste, only rarely and at great intervals one may detect a solitary black tent belonging to a party of nomadic shepherds, whose flocks may be grazing in the sheltered depressions of this great expanse, where better pasturage is possibly found. Or a wild kyang (*Equus hemionus Pallas*) may be seen careering across the plain, or standing and intently watching travellers from a distance. No town or village anywhere; such settlements as there are, are always found below the level of the plain, near the rivers, which have eroded their deep gorges through the horizontal post-tertiary deposits of Húndés. And beyond this great expanse of more or less level country may be seen the serrated range of snowy mountains, which frame in the view; to the north the great chain of

hills which, after the Hindu name of one peak, we have called the Kaílas range, sparingly covered with snow, although the average height of the range is probably not under 18,000 feet, and there are found in the chain heights of over 22,000 feet elevation; southwards the mighty rim of the Himálayas, closely plastered over with snow and glaciers; along the north slope of this snowy range another and lesser chain of hills runs parallel to it, which is not only entirely bare, but usually almost snow-free. Over this last range all the great passes into Tibet are found.

This, in few words, describes the orography of Húndés; for a detailed account of this region I refer to the excellent accounts of the brothers (Sir) Henry and (General) Richard Strachey,[1] who have travelled extensively over this province. Later on the brothers Schlagintweit[2] and the officers of the Survey of India,[3] have given accurate reports on the topographical features of Húndés.

Himálayan ranges

The area with which this memoir chiefly deals is situated for the greater part between the chain of the greatest elevations in the Himálayas and the line of watershed between the Ganges and Sutlej drainage, with part of the Spiti ground west of the latter river.

Viewed from any of our hill stations, perhaps best from either Ranikhet or Landour, we may observe one of the grandest panoramas in the world. Right across the horizon from north-west to east extends what appears as an unbroken chain of lofty snow-covered mountains, towering some 8,000 to 10,000 feet above the various hill-ranges which lie south of this snowy chain of peaks. The average elevation of this grand mountain line is perhaps not less than 20,000 feet, although many of the points in it rise to 22,000, 23,000 and upwards of 25,000 feet. Roughly speaking, from a level of 16,000 feet upwards, this chain is enveloped in perpetual snow. This is what I may call here, as it has been already called by former observers, the central range of the Himálayas. Colonel Godwin-

1 See list of literature.
2 Ditto ditto.
3 Ditto ditto.

Austen[1] has tried to trace the various lines of ranges continuously along the entire extent of the Himálayas from the Indus to the Bramapútra, and in a diagramatic map in Vol. VI of the Proc. Royal Geographical Society, he attempted to show the continuity of the main range between Drás and the Nepál frontier; although correct in the broad outlines, there are many minor deviations to notice in the diagram as given in the map. It is this range to which alone the name Himáchal (snow-mountain) or Himálaya ought properly to be given; the "abode of snow," where the sacred spirits of great men dwell with their gods, as the ancient Hindu scriptures tell us. In this range most of the great, snow-covered, perhaps inaccessible peaks are situated, amongst them the highest mountains of the world. But nevertheless this mighty range is not the divide between the plains of India and the high table-lands of Central Asia. Nearly all the more important rivers which rise within the Tibetan area flow through great gorges which traverse the Himálayan ranges; on the other hand, many of the Himálayan streams, amongst them the entire upper drainage of the Ganges, rise in the mountain valleys between the snowy chain just mentioned and the range which forms the water-parting between Húndés and the Ganges basin, and discharge themselves through narrow, V-shaped gorges into the lower hill-tracts below.

It has long been a point of discussion amongst geographers how far the name Himálaya should be extended when applied to the great mountain barrier which closes India along its northern frontier. Originally the names Himálaya (abode of snow), Himáchal (snow-mountain) were applied by the ancient Hindu writers to the great snow-covered ranges which form the highest portion of this mountain barrier, and within which the headwaters of the Ganges are found. The name Himálaya has, amongst European geographers, been generally accepted as defining the great barrier of mountains between the gorge of the Indus and the Bramapútra, and to include a belt between the plains of India and the southern margin or edge of the Tibetan

[1] Proc. R. Geogr. Soc. New Ser., V, 1883, 610; *ib*, VI, 1884, 83—87.

plateau, of which the Himálayas may be said to form the parapet and scarp.

Some seventy years ago[1] Herbert was the first to attempt a systematic examination of the Himálaya. Since then many other observers have worked in the same direction. I will here refer in few words to the various theories put forth. Most writers agree in the main about the distinctness of certain features, which I have already described, namely, that there exists a great Tibetan plateau fringed by high ranges; along its north side by the Kuenlun and south by the Himálaya, with several ranges more or less parallel running across the plateau itself. The Himálaya consists of a ramification of ranges, amongst which is most conspicuous (1) the line of water-parting between the Húndés basin and the Ganges drainage; (2) a chain of snowy masses, containing the highest peaks known at the present day, together forming the Himálaya of ancient Hindu geography; (3) a network of ranges, much lower than the snowy hills, which terminate in a more or less precipitous scarp facing the plains of India; (4) a range or ranges of low hills running parallel with the former,—the Siwaliks, etc.

Various views.

Different interpretations and various names have been applied to these features by the numerous geographical writers who have undertaken a systematic study of them.

B. H. Hodgson,[2] for instance, will only apply the name Himálaya to the line of water-parting; the snowy range is, in his opinion, not a continuous chain.

R. Strachey[3] rightly looks upon the entire belt of hills as the southern slope of the Tibetan plateau; the highest peaks according to this observer are not set in a continuous ridge, but are grouped together in masses and separated by deep valleys.

[1] Jour. As. Soc. Beng., XI, Suppl., pp. I—CIxiii.

[2] Jour. As. Soc. Beng., XVIII, 761—788 (1849); Sel. Rec. Gov. Beng., XXVII, 48—82.

[3] Jour. R. Geogr. Soc, XXI, 57—58; Quart. Journ. Geol. Soc., X, 249—253; Encycl. Brit., XI, 821

T. Saunders[1] includes the entire Tibetan plateau, with its fringing systems of mountains, as forming one structural whole, of which the Himálaya forms the southern segment of the girdle. The range in which the greater part of snowy peaks are found he calls the Southern Himálayas, whilst the line of water-shed, the "southern watershed" is termed by him the Northern Range.

C. B. Markham[2] describes the features of the Himálaya much in the same manner as the previous writer, but applies the name "Inner" or "Northern" range to the mountain chains which divide the Sutlej from the Indus, whilst he calls the line of water-parting, Saunders' northern range, the Central, and the line of snowy peaks the Southern Himálaya.

W. T. Blanford[3] agrees with Strachey, that the Himálayas form but the southern scarp of the Tibetan plateau, in the same manner as the Kuenlun defines the northern margin of the same.

H. B. Medlicott,[4] who adheres to the above view, divides the component ranges of the Himálaya into (1) Central, (2) Outer or Lower, and (3) Sub-Himálayas.

These are, in short, the principal views which have been formed within modern times by various geographers; I need not dwell here at any length on the theory fore-shadowed by Hodgson, that the line of great peaks is not a true range, but that these heights are situated on spurs which run out from the range which forms the water-parting. This theory advocated again by a writer in the Calcutta Review[5] and partially supported by the compiler of the North-Western Provinces Gazetteer,[6] has been ably disposed of by Markham and Saunders.[7] The snowy range, the Himálaya of the Hindu geographers, is a true range in every sense of the word,

[1] A sketch of the Mountains and River basins of India. Lond., 1870. Geogr. Mag. IV, 173—181 (1877).
[2] Geo. Mag. IV, 113—118 (1877).
[3] Manual of the Geology of India.
[4] Manual; Chap. III of the Gazetteer of N.-W. P., Vol. X.
[5] January 1877, p 145.
[6] Chap. I, Vol. X.
[7] As above referred to.

although cut into masses by rivers which rise in the valleys north of the line of snowy peaks.

Classification of ranges.

Fig. 1 shows the section across the Tibetan plateau, and its fringing belts of mountains. The southern rim of this plateau is formed by the Himálayas, and as the two ranges of the water-parting and the line of highest elevations are undeniably the most important features of the girdle of mountains, and in a sense are closely connected by common characteristics, I think the term "Central Himálayas" may be retained for them—a term already in use in the Geological Survey of India. The authors of the "Manual of the Geology of India" have proposed the following geographical divisions of the Himálayas:—

1. Sub-Himálayas (Siwaliks, etc.).
2. Lower or Outer Himálayas.
3. Central Himálayas, north of which are situated the—
4. Tibetan ranges.
5. Kuenlun.

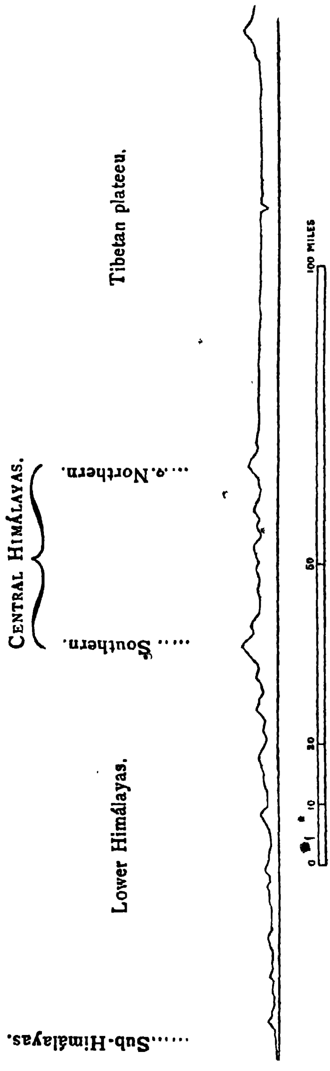

Fig. 1. Diagramatic Section of the Himálayan Ranges.

The term "Outer" Himálayas has already been used to define

various ranges north of the Central Himálayas, and should therefore be dropped; whilst the "Central" Himálayas should be sub-divided into the two ranges of which they consist.

I propose, therefore, for purposes of definition, to use the following terms in this memoir for the Tibetan table-land and its fringing rims.

(1) Sub Himálayas (Siwaliks, etc).

(2) Lower Himálayas.

(3) Central do. consisting of { *a.* Southern range (line of great peaks). *b.* Northern range (line of water-parting).

(4) Tibetan plateau with ranges.

(5) Kuenlun mountains.

Southern range Central Himálayas.

The Southern range of the Central Himálayas, as far as it is discussed in the present memoir, may be said to begin with the mass of the Nampa peaks on the North-West frontier of Nepál, and ends with the heights surrounding the Babeh pass south of the Spiti valley.

The snowy group of the Nampa peaks presents one of the most striking views in the Central Himálayas. It is a great gneissic mass between the Kali and Karnali rivers, of bold outlines and almost entirely enveloped in snow and ice. Huge glaciers descend down the deep ravines which have been eroded around its flanks. All but the northern spurs of this mass belongs to Nepál, and lies therefore outside the area under discussion here. This magnificent group of peaks, of which the Nampa is the central and highest point, is separated from the western continuation of the Central Himálayas by the deep V-shaped valley of the Kali river; between the latter and the Gori river rises the mass of the Dharma snowy heights, of which the Takachúll is the culminating point (22,660 feet). The deep cross-valleys of the Gori and Dhauli Gangas enclose the loftiest part of the Central Himálayas, which include the magnificent groups of heights of the Nanda Devi (25,660 feet), the Trisúl (23,406 feet), the Dunagiri (23,184 feet) and others. Beyond the Dhauli Ganga gorge the

Southern range of the Central Himálayas continues in a north-west direction; the Kamat (25,443 feet) with the Mána (23,862 feet) and a number of minor heights form the range between the Dhauli Ganga and Sarsuti rivers. West of this region, and bounded by the gorge of the Bagirathi and Jádh rivers, lies an almost inaccessible mass of snow-clad mountains; of the well-known peaks I will only mention such as, for instance, the Kedarnath group, which consists of the Karchakunt peaks (21,785 feet), the Bhartekanta (220,840 feet), Satopanth (22,388 feet) and Badrinath peaks (22,395, 29,619, 22,901 feet,etc.) and many others.

The most prominent groups of peaks are those of the Badrinath and the Kedarnath heights, at each end of this portion of the Southern chain, and they are connected by a snow-covered range, over which neither path nor pass is known to cross into Tibet. This part of the great Himálayan range is supposed to be the holiest; from amongst its peaks the head-waters of the Ganges rise, and several very sacred Hindu shrines are found amongst its ice-choked valleys, as, for instance, the temples of Badrinath, Kedarnath and Gangotri.

Between the Bagirathi and Sutlej the Southern chain of the Central Himálayas forms the political boundary between Tibet and Bisahir, where it breaks up into a number of ridges with heights of from 18,000 to 22,000 feet; the Sutlej has eroded a deep V-shaped valley through its entire width, which near Shipki becomes a narrow gorge between steep rock-walls of gneiss with great granite intrusions. So far this chain is running almost north to south; beyond the Sutlej it breaks into two distinct ranges or groups of ranges: one, running almost east to west, forms the water-parting between the Sutlej and the Spiti valley, the other continues a northward course into Tibet.

This is the Southern range of the Central Himálayas, known commonly as the "snowy range" or as the natives themselves ordinarily call it the "baraf-pahar" (snow mountain). Parallel to it, sometimes separated by more or less broad valleys of great elevation (15,000 to 16,000 feet sea-level), sometimes connected with it by ridges which form the water-partings of the lateral drainage of these ranges, runs the *Northern* range of

Northern range: Central Himálayas.

the Central Himálayas. There are fewer great peaks found in it; on the other hand it is more intact as a continuous range, being only traversed by one river, the Sutlej, within the area examined by me. It forms therefore a "divide" between the drainage of the Ganges and the Sutlej. It is comparatively snow-free, except in the higher tracts of the Lissar and Byans headwaters. All the great passes which lead into Tibet between Spiti and the Nepál frontier are situated in this range. Structurally it consists of a system of great flexures of sedimentary rocks; practically all the diagrams figured in the plates illustrate sections and profiles seen in this Northern range of the Central Himálayas.

Tibetan table-land north of it.

North and north-west of the Central Himálayas extends the Tibetan table-land; this again is formed by a number of folds, just in the same manner as is the Himálayan girdle south of it, with this difference that the synclinal troughs, within which the Sutlej and Indus flow, are filled by enormous, more or less horizontal deposits of post-tertiary age, probably of lacustrine origin. So, for instance, the Húndés plateau, already described in its broad outlines, is nothing else but the filled in trough in which the Sutlej now flows.

Passes into Tibet.

As already said, this Northern range of the Central Himálayas is a continuous ridge, and is the water-parting between the Gangetic system and the Sutlej. Within the limits of the ground examined by me, this range is only pierced by one river, namely, the Sutlej, which flows through a deep V-shaped gorge near the Shipki village in Húndés. East and south-east of this point the only access to the high plateau of Húndés is by way of a number of more or less difficult passes. They are all closed during the winter and few of them are open for the traffic between India and Tibet before the end of May each year. With few exceptions they are only passable to men and sheep, the latter being generally used as beasts of burden. They vary in height above the sea-level from about 16,000 to 19,000 feet, and in most cases are partially obstructed by glaciers and their moraines.

Fig. 2. Dharma Pass seen from Dobali camping ground.

The following are a few of the principal passes into Tibet: Tsang Tsok Lá (17,490 feet), Mána (17,890), Niti (16,628), Marchauk (19,000 about), Balch Dhura (17,590), Uttar Dhura (17,590), Dharma (18,510), Langpaia Lék (Lankpya Lek of the map) (18,150), Lipu Lek (Byans) (16,780), etc., etc.

River systems.

The rivers which drain the country examined by me belong to two systems: namely, to the Indus and the Ganges. The provinces of Kumaun, Garhwál and the native state of Tiri Garhwál are drained by a series of big streams which unitedly form the head-waters of the Ganges system, whilst the high regions of the Húndés plateau of Tibet, Bisahir, Kunawár and Spiti belong to the Indus basin. These two systems are separated by a watershed, which between the Nilang and Byans areas coincides with the Northern range of the Central Himálayas. The high peaks north-west of Nilang form a nucleus, from which the line of water-parting between the two systems branches off to south-west, dividing the Bagirathi from the Jumna valley.

Indus system.

That portion of the Central Himálayas and of Húndés which belongs to the Indus system as far as it is described in these pages, is drained by the Sutlej and its numerous Tributaries. The Sutlej itself rises in the Manasarowar lake district in Húndés, and flowing in a north-western direction drains a large portion of the province of Húndés, finally entering the Himálayas by a deep V-shaped valley near Shipki, from whence it traverses the entire width of the Himálayan ranges. In Húndés itself numerous smaller streams join it from both sides; they and the Sutlej itself have eroded deep troughs and occasionally narrow gorges in the young-tertiary deposits which form the high plateau of this part of Tibet. That of the Sutlej itself is fully 1,500 to 2,000 feet below the level of the plateau, which varies from 15,000 feet sea-level near the southern margin to about 13,000 to 14,000 near the centre of the high plain. In this deep V-shaped channel, or in that of its tributaries, nearly all the permanently inhabited places in Húndés are situated; so, for instance, Kyunglúng, Dongpú, Dapá, .

Tsaprang, etc. In plate 12, I have given a view of the Húndés plain with Dongpú, which will illustrate the peculiar feature of this deep valley, so totally different from any thing seen in the Himálayas. I have since observed similar deep valleys which have been eroded by the Central Asian rivers, as, for instance, the Múrgháb, below the fort of Bála Múrgháb, or the Téjend (Hari rúd) north of Pul-i-Khatún, where the steep sides of the rivers consist of upper tertiaries. Amongst the numerous tributaries, which flow into the Sutlej from the southern margin of Húndés, I will here only name the Shanki river, the Dongpú river and the Hóp Gádh; they have eroded deep gorges through the triassic and younger mesozoic systems nearer their sources, entering further north into the softer and more or less horizontally bedded tertiary rocks.

Within British limits in the Himálayan belt, the Sutlej receives many important tributaries. Amongst them I may name on the left side : the Taklakar stream; the Todung-gar and the Baspa river. From the right side join the Spiti with its many confluents; the Thanam stream.

Ganges drainage.

All the streams which together form the sources of the Ganges river rise within the area described in this memoir. The water parting between the Ganges and the Sutlej basin has already been dealt with in its outlines. I may add that a spur of hills running from east of Nilang through the Chini peaks to Simla completes the divide between the two basins. Great groups of peaks separate the confluents of the Ganges west of the Nepál frontier into four distinct drainage basins, but according to the native geographers only the two central groups form the holy Ganges, the two outer ones being the Júmna on the west, and the Káli river on the east. The Ganges head-waters rise in the fine groups of the Nanda Devi (25,660 feet), Kamet (25,443 feet), the Badrinath (22,901 feet) and Kedarnath (22,844 feet) peaks and consist chiefly of two great branches, the Alaknanda and the Bhagirathi rivers, each with several large confluents.

The Bhagirathi rises in the great Gangotri glacier (fig 3.), from which it issues as a big torrent, and after forming several narrow and deep gorges in the granitic

Bhagirathi river.

Fig. 3. Gau Mukh; source of the Bhagirathi branch of the Ganges

belt, flows onwards to join the Alaknanda at the foot of the Lower Himálayas. Its principal tributary, the Jádh Ganga, joins with many side streams from its right side.

Alaknanda river.

The Alaknanda is formed by the head-waters of the Dhauli and Vishnu-Gangas, which are separated by the Kamet peaks. In its further progress through the hills the Alaknanda takes up a number of important tributaries, finally uniting with the Bhagirathi before emerging from the lower hills into the plains.

Júmna.

West of the Bhagirathi flows the Júmna with its many tributaries. The head-waters of this system rise amongst the great heights west of Nilang, and the streams which further on form the Júmna have eroded a deep basin between the ranges which on one side divide it from the Bhagirathi, and on the other from the Sutlej.

Káli river.

West of the true Ganges branches is the drainage basin of the Káli, which forms the boundary between Kumaun and Nepál. One of its sources is in the Byáns pass, where it rises, as an insignificant stream, at the foot of a small glacier. But this is soon re-inforced by numerous glacier streams and important tributaries on both sides, so that it forms, further down, one of the largest contributions to the Ganges. Amongst the streams which join the Káli on its right side are the Kuti Yangti, the Dharma (with the Lissar) Ganga and the Gori Ganga. They all cut through the complicated folds of the sedimentary series which form the northern range of the Central Himálayas and often expose good sections.

All these rivers are of great volume and possess strong currents; as, for instance, the Káli river during a course of about 130 miles descends 15,000 feet, or about 115 feet per mile. Most of them constitute formidable obstacles to travelling in those high regions, and even many of the minor streams are only fordable with difficulty and often with considerable danger.

A very large part of the Central Himálayas is situated above the

Glaciers.

line of perpetual snow, which, it has been ascertained,[1] ranges between 15,500 and 16,000 feet sea-level along the southern chain, and at a somewhat higher elevation along the northern chain and the Tibetan ranges beyond. Nearly every one of the high valleys situated within the limits of perpetual snow has its glacier. Some of them are of very large proportions; for instance, one of the Raikana glaciers near Niti is 7½, the other 8 miles long. The Nanda Devi is surrounded by huge glaciers: two, which descend from this mountain mass on its north side, are respectively 12 and 14 miles long, whilst the Bagini glacier is 10 miles, and the Kosa 7½ miles in length.

Several very large glaciers are found in the Mána and Gangotri area; the three branches of the Gangotri glacier are respectively 14, 15 and 5 miles long. The Mána glacier, a huge sheet of ice and moraines, is fully 16 miles long.

To describe any of these enormous glaciers in detail would be quite superfluous after the excellent account General R. Strachey has given of the Pindari glacier[2]; its features are so similar in every respect to those of many others, that I may therefore refer to that paper as being a summary of what may be said of the glaciers of the Himálayas generally. In the frontispiece will be seen (1) the middle part of one of these glaciers (Kedarnath), which, comparatively speaking, has a gladual slope downwards and is completely covered with the angular debris; (2), the upper portion or catchment area of the glacier which, enclosed in a steep trough, is not only free from debris, but cut up by lateral crevasses. In fig. 4 a copy from a photograph, an end moraine is seen, pushed along by the long and almost level tongue of the end of the Bambadhúra glacier. I have also shown in pl. 14, the great glacier streams which, more or less parallel, descend from the Bambadhúra heights down to the Lissar valley; the Lissar river itself has to erode its bed through the end moraines of successive glaciers which project into the valley from the ravines on the right side.

[1] Jour. As. Soc. Beng., XVIII, 287, etc., etc.
[2] Jour. As. Soc. Beng., XVI, 794, 812,; *ib.*, XVII pt. II, 203—205, etc.

Fig 4. End-Moraine of the Bambadhura glacier (from the north)

30).

During years of travelling in those high regions, I have searched, but in vain, for striated and polished boulders amongst the moraines of glaciers, such as one is familiar with in Alpine regions. Striæ on glacial boulders I have never met with in the Himálayas. I believe the sub-ærial denudation, and the rapid weathering of the rocks, must obliterate anything like grooving or ice-scratches.

The rock-walls which form the glacier troughs are almost invariably roughly worn, obscured also by masses of debris, and are wanting in those regular and smooth surfaces one usually associates with glacier action. And the blocks which find their way through crevasses into the interior, or towards the base of the glaciers, finally reach the glacier stream, when they are invariably subjected to the ordinary rolling and wearing action of water. The blocks embedded in the accumulation of moraine matter at the lower end of the glaciers, I found always to be angular or sub-angular very much weathered fragments, on which I absolutely failed to discover glacial scratches. The only traces of erosion, which might be attributed to glacial action, I met with in the Mána valley. The gneiss walls which form the right side of the Mána valley, near the village of this name, are worn smoother than is usually seen in these high regions; and there are indistinct traces of parallel groovings, which possibly are of glacial origin, but if so, it indicates that the glaciers of this valley have once extended far below the level at which we find them at present.

It may be supposed that an area covered over to a large extent with glaciers and perpetual snow is an extremely difficult one for the explorer; indeed there are several portions of these mountains which had to be left unexplored. By far the most inaccessible areas I found on the north side of the Nanda Devi group of peaks, and near the Badrinath and Mána peaks. Fortunately for me all these localities are within the belt of crystallines, and the oldest and non-fossiliferous rocks (the vaikrita and haimanta systems); all the fossil-bearing strata of the succeeding systems are comparatively free from snow and ice. The most inaccessible parts of the hills

proved to be the valleys north of the Gangotri and Mána glaciers, the Girthi valley in Johár, and the Lissar valley in Dhárma. Parts of the first are altogether inaccessible; whilst the remainder of it even was most difficult to travel over. The Girthi valley (plate 10) is a deep trough, with an almost vertical trias-carbon cliff forming its right side, and with enormous glaciers descending from the Nanda Devi peaks on its left side. The Lissar valley is similar; the eastern or left side of it is formed by more or less precipitous cliffs of palæozoic and trias beds, whereas on the right side of the river is a succession of huge moraines and cones of debris, shot out by the large glaciers of the Takachull and Bambadhúra peaks (fig. 4 and pls. 14, 15 and 16).

Glacial deposits.

In a mountainous country, subject to extensive erosion by rivers, weathering and sub-ærial changes, it may be expected that distinct traces of former glaciation have entirely disappeared, or are at least very difficult to recognize amongst the more recent results of glacial or river erosion. Nevertheless, here and there one may detect isolated traces of glacial deposits of by-gone periods. Amongst them may be reckoned the high-level terraces which are now found far above the present base of the valleys, forming occasionally mere patches which are preserved from complete denudation in sheltered parts of the great river-gorges which are cut through the Central Himálayas. It is highly probable that glaciers did once extend to far below their present level; for instance, the Milam glacier must once have reached far down the Gori valley, to a point somewhere half-way between Milam and Munshiari, where I found moraine matter, through which the Milam river has eroded its present bed.

I met with much clearer instances of the former extension of glaciers in the tracts north of Niti. There, the heights below the Daldakharak group of peaks, on the right side of the Dhauli Ganga, are profusely strewn with boulders of metamorphic rocks, chiefly of granitic gneiss, such as composes the greater part of the range between Niti and the Kamet.

Fig. 5. Glacial deposit in the valley of the Dhauli Ganga near Ganes Ganga.

The entire mass of the Daldakharak consists of palæozoic rocks, silurian and carboniferous, in which systems I have not met with any rocks of gneissic character in the Himálayas. The nearest point where these gneissic boulders could have come from is in the enormous heights overhanging the right banks of the Raikána river, in fact, the hill groups of the Kamet and Mána.

Perhaps the most suggestive instance of boulder deposits I have observed on the Niti pass itself; on the very line of water-parting formed by this pass I found rolled boulders of carboniferous rocks, chiefly white quartzite, and red crinoid limestone, inclosing fossils. They repose on rhaetic beds, which form the upper part of the entire range. The nearest ground where carboniferous rocks are in situ lies south of the Niti pass chain, and is formed by a range of rugged hills which strike approximately from

Boulders on the Niti pass.

south-east to north-west. These carboniferous beds dip below the trias and rhaetic of the Niti pass range in perfectly normal order (fig. 16). I have examined both these ranges carefully in every direction, having had the good fortune to be able to re-visit the ground again in 1882, and have found no other locality where the carboniferous boulders could have been derived from. I believe them to be of glacial origin; but even had they been transported by water, they must have been derived from the range south of the Niti pass ridge, and the natural consequence of this supposition is that the drainage (water or ice) must have flowed northwards once, in order to deposit the palæozoic boulders on the upturned edges of the rhaetic limestone which forms the Niti pass range. I believe the boulders of the Niti pass, and the north-east slope of the lower Daldakharak, were deposited at a time when the Dhauli Ganga had not yet worked back its course through the area north of the Kharbasyia gorge, and when the drainage of that part of the Himálayas was flowing in a northern direction, belonging in fact to the present Húndés basin. This reversion of the drainage I suppose to have been caused chiefly by the folding and wrinkling process, which has added folds on folds to the mountain system of the Himálayas. That such folding actually continued *after* the deposition of the young tertiaries of the Húndés basin is clearly shown by the fact that near the edge of the basin, the beds of the tertiaries are everywhere raised up on end, as is also the case along the southern margin of the lower hills, which are skirted by the Síwaliks. In stating this supposition, I do not assert that the gigantic folds, which at present form the Northern range of the Central Himálayas, date from post tertiary times; but I think it highly probable that in the general wrinkling process, which must still be going on at the present time, this Northern range was perhaps one of the later formed flexures, and gradually became a water-parting, at the same time, when that portion of the drainage from the Southern or main range of the Central Himálayas, which is still flowing towards the plains of India, gradually cut backwards through the former water-parting. That the supposition of a still existing

and continued wrinkling process is based on good grounds, I will show later on when discussing the post-tertiaries of Húndés, and when comparing the structure of the Himálayas with the neighbouring regions.

Lakes.

Large lake basins are entirely wanting in the Himálayan area between Spiti and the Nepál frontier. Of smaller lakes and tarns there are a great number, most of them being situated in the end moraines of glaciers. But the best known, and at the same time most picturesque ones, are those situated in the Lower Himálayas of Kumaun, namely, the lakes of Naini Tál, Bhím Tál, Malwa Tál, Sát Tál, Kurpa Tál, Sária Tál and Náukuchia Tál. Divergent views have been held regarding the origin of these lakes. One author[1] believes them to have been formed by landslips, which closed the valleys partially and so converted them into lake basins; another[2] considers them to be formed by glacial agency.

Although the Naini Tál lake area is not included in the ground which is to be described in these pages, I will nevertheless state here a few facts, which closely bear on the stratigraphy of the Himálayas. As regards Mr. Ball's theory of blocking up of the Naini Tál valley by slips from either or both sides of the hills forming the valley, it may be said, at once, that it is disproved by the fact that the southern end of the lake basin is formed by rock in situ. The ascertained bottom of the lake is below the upper edge of the rock which really forms the southern side or dam which closes the lake; at the same time slips have contributed to the heightening of this dam. On the other hand, Bhím Tál could not have been formed by slips, and Naukutchiá or Sát Tál are clearly inclosed in rock (chiefly Trap) basins. Again, as to the glacial origin of the lakes there is no evidence whatever in my opinion. Rock-scratches and moraines are alike absent, and there are no distinct glacial features of any other kind available; in fact the shape of the small lakes of Naukutchia or Sát Tál is distinctly against the supposition that they were formed by

[1] Ball, V.—On the origin of the Kumaun lakes, Rec. Geol. Surv. Ind., XI, 174—182.
[2] Theobald, W.—On the Kumaun lakes, Rec. Geol. Surv. Ind., XIII, 161—175.

glacial action. Both these small lakes are completely rock-surrounded, with an insignificant outlet, differing in every characteristic from known glacial basins.

The hill ranges immediately south-west of the Naini Tál lake suggest the true origin of the Kumaun lakes generally. The limestone which rests conformably on calcareous shales in that area, is, like most limestones, much jointed, and in consequence all the drainage finds its way through the joints into the underlying shales. These become disintegrated and are gradually carried away, whilst the thick limestone beds sink down to the level which was formerly occupied by the shales. This phenomenon may be seen in the range which forms the south-western side of the lake, and at many other localities in these hills. Under certain circumstances such a process must result in the formation of "cirques,"—circular valleys—Einbruchsthäler—which become filled with water as soon as a sufficiently water-impervious layer of alluvium has formed in the basin resulting from this underground denudation.

Another factor which possibly helped this denudation still further, is the folding and wrinkling process which must be supposed to be going on still. It is conceivable that this action has resulted in the elevation of the outer edge of the Kumaun hills, north of which are now the lakes, dammed up by this rising outer edge.

Even with both these factors in active operation, the possibility is not excluded of some of the "dams" having been supplemented by rock slips, coming down from the hill-slopes which inclose the valleys.[1]

Several lakes of large extent exist in the Húndés province of Tibet.

Lakes in Húndés.

The Manasarawar lakes (Tso Mapang) of Húndés with the Rakas Tál (Tso Long) lie north of the easternmost corner of the area which I now report on. They belong to the drainage basin of the Sutlej, which, during part of the year, flows from the Rakas Tál. Both lakes are connected by a running channel.

[1] Whilst correcting the proof-sheets of this "Memoir," Pt. 4 of Vol. XXIII of the "Records" reaches me; in it Mr. Middlemiss suggests a similar origin for the Naini Tal lake.

I have not been able to visit them, as the Húnias keep now a strict watch on Europeans who may wish to penetrate so far. I found a series of three smaller (fig. 6), but very picturesque, lakes north of the Mána Gádh, in perhaps the most inaccessible region I have yet

Fig. 6. One of Jessie's Lakes in Tibet.

visited. They are drained by a stream which runs into the Hóp Gádh, and they are surrounded by snow-clad heights and bleak mountain scenery, relieved by strips, near the margin of the lakes, of flower covered meadows. Nothing, perhaps, can equal the utter desolation and wildness of their surroundings. Although within some thirty miles of the grazing grounds of Poling and Dogwa Aúr, the spot is apparently never visited by any of the nomads who tend their flocks of sheep on the Húndés plain. Surrounded by stupendous and snow-covered heights, which, as I am assured, have become much more inaccessible within the memory of man, these lakes do not seem to have been visited by any of the few native travellers who use the Mána pass to reach Tsaprang on the Sutlej. I could not learn that they were known by any name, and so I put them down in my diary as "Jessie's lakes."

Their origin is clear enough; huge fans from side valleys have partly dammed up the main valley, met on the other side by the talus of the opposite hill range. The trickling stream which flows through the valley (a tributary of the Hóp Gádh) has forced a narrow outlet at the third (the lowest dam), but in the case of the two upper lakes (the larger one) the drainage is effected partly by overflow over the dams, and partly by filtration through the debris which form them.

Spiti valley.

At the foot of the Manirang pass in the Spiti valley, at the western slope, leading up to the small glacier which descends from the pass is an instructive example of a small lake formed by the damming up of a valley by the moraine left by a former glacier (see fig. 7). A well-

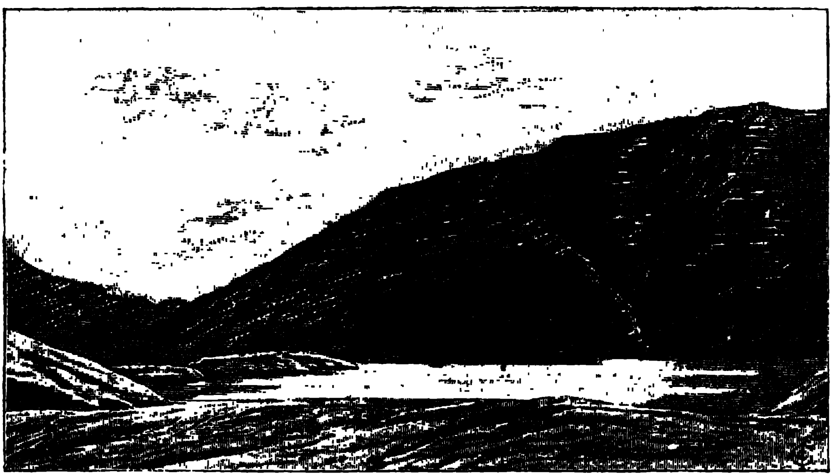

Fig. 7. Glacial Lake at the foot of the Manirang Pass in Spiti.

defined and broad dam, being the end moraine of a glacier, closes the valley now partially, whilst the talus from the inclosing hills bars the intervening space left. Immediately above, the valley is filled, forming thus a small lake, about ¾ mile long by ¼ mile broad. The dam, or end moraine, exactly marks the spot to which once the Manirang glacier must have extended,—about five miles below the present limits of the glacier.

CHAPTER III.—STRATIGRAPHICAL FEATURES: CRYSTALLINE ROCKS; PALÆOZOIC GROUP.

The principal features of the structure of the Himálayas are repeated in almost every section within the system. I have already shown that the Tibetan plateau, with its fringing belt of the Himálayan ranges is formed by a system of more or less parallel flexures, which can generally be followed for long distances along the southern rim of the Tibetan plateau.

H. B. Medlicott [1] proved that the lower ranges of the Himálayas, with the tertiary belt, had undergone the same crushing and folding process which has shaped the Himálayan system into parallel ranges. For the North-Western Himálayas Lydekker [2] proved a similar arrangement of folded flexure, and Stoliczka [3] has shown how such flexure may eventually result in inverted faulting. On a former occasion [4] I have given my own interpretation of the geological structure of the Kumaun Himálayas, to which I have little to add. I believe that the section described in that paper represents the geological structure of the greater part of the Central Himálayas; a certain amount of faulting and intrusion of igneous rocks have modified the normal order in several sections; but in general outlines the Himálayas consist of a succession of inverted flexures, leaning over towards the south-west. Two great anticlinals, at least can be distinguished, which inclose synclinals, within which the fossiliferous stratified rocks are preserved.

These synclinals form long irregular strips inclosed between immense flexures of older crystalline formations. The southern range of the Central Himálayas is formed of, perhaps, the largest of these anticlinals; the upper portion of its arch having been destroyed by denudation, there is only left what might be taken to be a conformable series of metamorphic strata. North of this inverted flexure follows a huge synclinal trough, in which all the highly contorted and crushed sequence of sedimentary rocks are inclosed, which form the subject of this memoir.

[1] H. B. Medlicott, Mem. Geol. Sur. Ind., 1864, Vol. III.
[2] R. Lydekker, Cashmir et. Mem. Geol. Surv. Ind., 1883, Vol. XXII.
[3] F. Stoliczka, Mem. Geol. Surv. Ind, 1865, Vol. V, p. 34.
[4] Rec. Geol. Surv. Ind, Vol. XIII, p. 84.

In an area which has suffered such a degree of contortion and lateral crushing, one must naturally expect to find much faulting. Indeed such is the case, and in many instances and over great distances, the inversion of the folds has resulted in oblique faults of great magnitude, producing often that scale-structure so common in most areas of folding.

The valley of the Sutlej in Húndés will, I believe, be found to be a line of great dislocation; the mountain range (Kailás) which divides the Sutlej from the Indus valley, is by all accounts a repetition of the Central Himálayas, *i.e.*, it consists of an anticlinal of metamorphics followed by a synclinal of sedimentary strata. None of the fossiliferous series of the northern range of the Central Himálayas seems to be found along the southern slope of the Kailás range, and it is therefore probable that this mountain range is simply a repetition, by faulting, of the Central Himálayan system.

DESCRIPTION OF THE GEOLOGICAL FORMATIONS.

1. Crystalline rocks.

My work in the Himálayas, which occupied several years, was chiefly devoted to the study of the sedimentary rocks, which form a more or less continuous belt north and north-east of the Southern or highest range of the Central Himálayas. It was partly owing to want of time, and partly necessitated by the difficult nature of the country, that I had to limit my detailed observations to the fossil-bearing formations; as regards the belt of crystalline formations, I could, in most cases, do little more than just trace out the boundary between them and the overlying sedimentary series. The main mass of the Himálayas, Central and Lower ranges of it, is formed of crystalline rocks of enormous thickness. So far seems certain, that within the crystalline rocks two distinct systems exist; namely, an older one of granitic gneiss, formerly called the central gneiss, and a schistose series which apparently overlies the former. Of the granitic gneiss I will only say this, that later studies[1] within the

[1] McMahon, C. A.—Rec. Geol. Sur. Ind., X, 204-223; *ib.*, XVII, 53-73; *ib.*, XVII, 168-175; XX, 203-205; Geol. Mag. 3rd Dec., IV., 212-220.

gneissic area have shown that the gneiss which forms the nucleus of nearly all the ranges south of the Southern Central Himálayas is really a granite, and that this granite must have undergone extensive metamorphism.

Schistose series; vaikrita system.

So much seems certain that this granitic gneiss is itself the oldest rock exposed in the Himálayas, or is at least now in place of the oldest formation, which is overlaid, conformably I believe, by a schistose series of great thickness, which varies much in lithological composition, and is well seen in all the sections north of the Southern chain of the Central Himálayas. Amongst the members of this series micaceous schists, talcose rocks, phyllites and gneiss are commonest. Between it and the next following, clearly sedimentary rocks, which I have termed the haimanta system, a clearly defined boundary scarcely exists. In nearly all sections which I have hitherto examined between the Kali river and Spiti, the schists seem to pass gradually into the overlying slates, phyllites and quartzites of the haimantas. The latter therefore belong structurally to the schistose strata below, and take part with them in all the complicated flexures and minor folds which have affected the Himálayas generally. This series of schists I distinguish north of the Central Himálayas as the vaikrita[1] system.

Passing from the tertiary hills which skirt the southern margin of the Himálayan system, to the line of the Tibetan watershed, one crosses, as I have already said, a number of ranges within which, broadly speaking, several lines of flexures and dislocations run more or less parallel to each other.

The older gneiss, the vaikritas and the haimantas are laid into a succession of anticlinals with great synclinals in between. The whole has suffered such extensive denudation that all the arches of the anticlinals must have been carried away in very early periods, so that now many of the flexures might easily be taken for normal successions of great thicknesses of strata, and only the repetitions of a long series of strata in reversed order will show that one really moves over a denuded flexure instead of a series of beds all dipping

[1] Vaikrita, Sanskrit for metamorphosed.

in one direction and forming a great sequence. It is therefore only in the synclinals that I met with the haimantas above mentioned, whilst the older granitic gneiss generally appears only in the anticlinals, or near the base of rock sequences along lines of dislocations.

Several such synclinals (often reversed) are found within the belt of the Lower Himálayas, which enclose long strips of sedimentary rocks enclosed by metamorphic schists. I am myself convinced of the probability, which is based not only on lithological similarities, but also on stratigraphical evidence, that these inclosures of sedimentary rocks are, in greater part, if not entirely, members of the haimanta system, which is well exposed north of the Southern range of the Central Himálayas. I shall have to refer to this question later on.

The Southern range of the Central Himálayas coincides more or less with the most important of the great anticlinal flexures which occur within the crystalline belt. It is generally an immense reversed flexure, and as the top of the arch has been denuded away, we see now nothing but a succession of beds steadily dipping to north or north-east at an almost uniform angle of from 30 to 40 degrees. Were it not that one traverses from south to north respectively; metamorphic schists (vaikritas), and gneiss, granitic gneiss, and again vaikritas, it would be difficult to decide whether one has to do with an inverted flexure or a normal sequence, in which the schists to the south form the oldest beds. The vaikritas which rest conformably on the granitic gneiss of the Southern range along its northern slope, pass as will be seen gradually into the haimanta system. The boundary between the two systems could therefore only approximately be laid down on the maps.

In addition to the two great rock groups of the metamorphic belt, *i.e.*, the granitic gneiss and the schistose strata of the vaikritas, there are intrusive rocks, which play an important part in the geology of the Himálayas. Foremost amongst these rocks must be considered the great masses of granite which penetrate the older granitic gneiss and schists and are even seen to traverse the overlying haimanta system. The granite forms usually a perfect net-work of veins in the vaikritas, and in the older masses of the granitic gneiss, but in places these veins swell out to immense pro-

Granite.

portions, and then the granite may be seen in the form of great massifs. The great peaks of the Central Himálayas are nearly all of them within the line of this granite intrusion, and the Kamet, the Mána, Badrinath, Kedarnath and Gangotri peaks are such granite massifs. Further west it is in very strong force, and not only traverses the crystalline rocks of the Sutlej valley as a perfect net-work of veins, but thickens out into several masses, as for instance west of Shipki on the Húndés frontier.

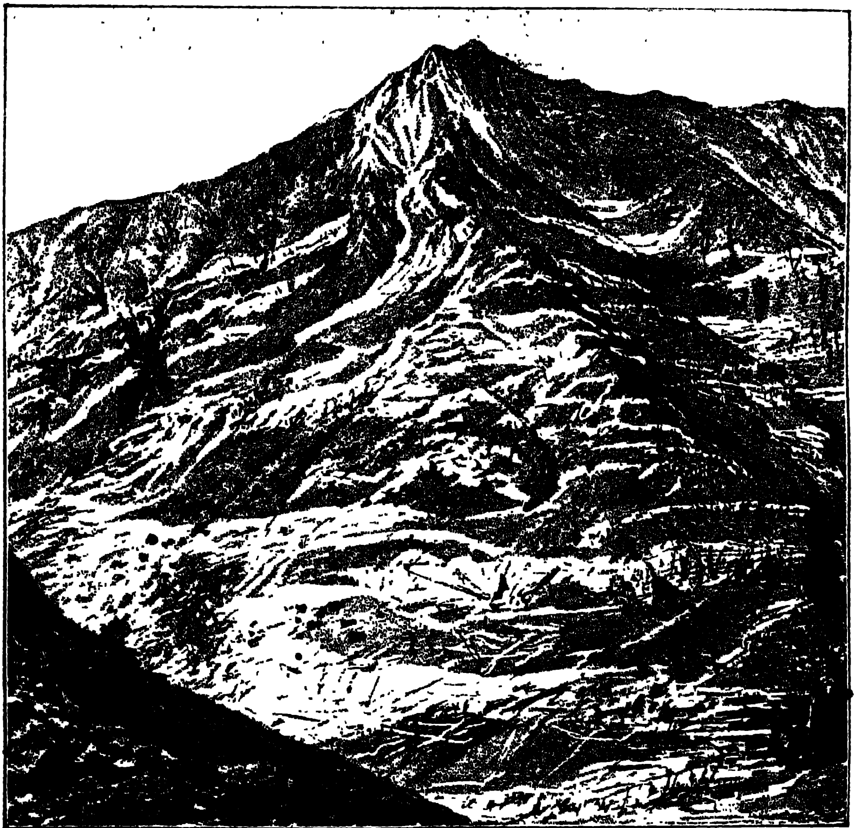

Fig. 8. Granite intrusions in hornblendic gneiss of the Shipki gorge.

Mineralogically considered it approaches closely the granitic gneiss of the Central Himálayas, but its mode of occurrence is distinctly intrusive; it is chiefly composed of muscovite, quartz and albite with

accessory minerals of which the most common are tourmaline, garnet, beryl and others. Kyanite I found both in the gneiss and the intrusive granite; it occurs with beryl in considerable quantities both at Niti and south of Shipki, but is met with in many other localities.

The granite is clearly of phorphyritic nature, and its form of occurrence an intrusive one. In fig. 8 will be seen the complicated manner in which the net-work of granite penetrates the crystalline series. The right side of the Sutlej valley forms in the gorge south of Shipki an immense, and almost perpendicular rock-wall, in which the light-coloured albite granite veins contrast strongly with the grey of the hornblendic gneiss, which composes the range through which the Sutlej has eroded its course.

Fig. 9 shows hornblendic granite veins in phyllites belonging to the lowest beds of the haimantá system of Tukchung in the Lissar

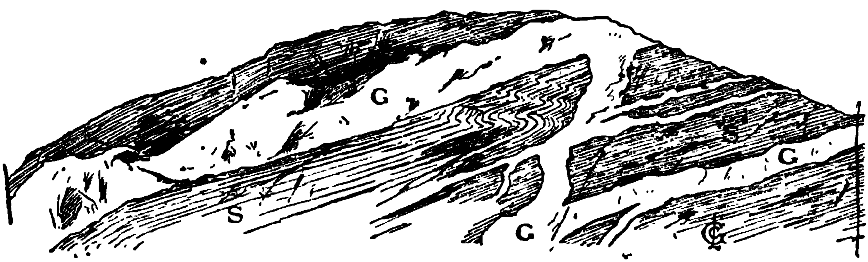

Fig. 9. Granite intrusions in haimantas ; Tuktung in the Lissar valley.

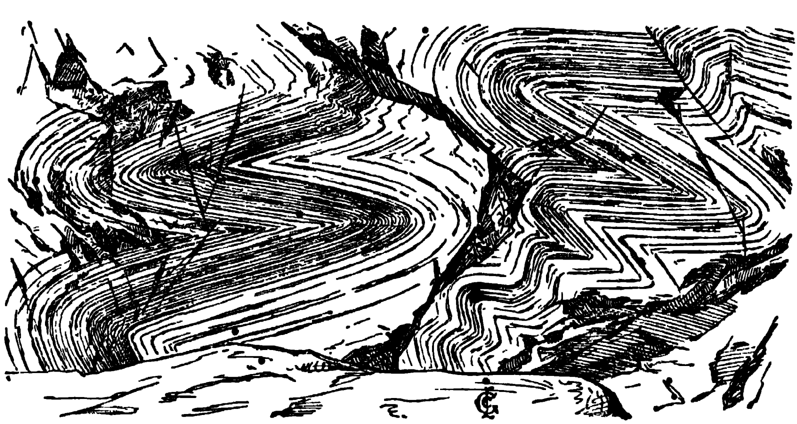

Fig 10 Contorted haimantas near Baling in the Lissar valley.

valley, which is traversed in every direction by veins of this rock varying in thickness from half an inch to many yards. There I also noticed the change which has taken place in the lithological aspect of the mother-rock, which from a clay-slate (as is seen in adjoining less altered parts) has been altered into a garnetiferous, sometimes micaceous schist, highly contorted and plicated.

The fact that this granite occurs chiefly in long lines, coinciding with the general strike of the flexures which form the Himálayas, seems to point to the probability that the granite masses with their neighbouring numberless veins have intruded along lines of fissures and dislocations formed along lines of greatest tension. Indeed, we see along the boundary of the haimantas with the crystalline rocks in the Niti area, that there the entire thickness of schists and semi-altered schists of the vaikritas which elsewhere intervene between the granitic gneiss and the sedimentary strata, is absent altogether, but instead of it, I found great granite intrusions which penetrate even the quartzites and slates of the haimanta system, whilst further north-west the granite swells out to enormous proportions. I think it very possible that there exists a long line of dislocation which partially cuts out the older slates and schists of the vaikritas.

Basic eruptive rocks.

Besides the extensive granitic intrusions already noticed eruptive rocks of another kind play an important rôle in Central Himálayan geology. A series of basic rocks, amongst which serpentine, diallage, epidote and basaltic varieties are prominent, occurs throughout the Lower and Central Himálayas, and are in very strong force both in Western and Eastern Húndés. They, like the granite, I believe, appear along lines of dislocations and here and there enter the neighbouring strata as dykes. In some places these rocks have effected immense changes in the lithological character of the neighbouring formations; for instance the nummulitic rocks of Húndés (north of Niti) have in a large measure been converted into a semi-crystalline formation, which one would naturally identify with some of the lower palaeozoics (haimantas) which they resemble, were it not that on the one hand their

position between the cretaceous and the younger middle tertiaries and on the other, indistinct traces of *nummulites*, determined their geological age accurately.

The great outburst of basaltic rocks along the Húndés dislocation, between the Manasarawar lakes and Western Húndés, partially hidden under younger tertiaries, is the only "trap" which I have to record as occurring actually within the limits of the area reported on. But in the belt of the Lower Himálayas, as far south as the Siwalik boundary, basic eruptive rocks are frequent, but seem generally to keep in lines parallel to the strike of the flexures, and I have little doubt they occur along lines of dislocations.

Age of granites and traps.

As regards the probable age of the granites, I have nothing but conjectural evidence to offer. So far it is certain that the granite must be *younger* than the haimantas, which they penetrate.

The exact period of its appearance in the Himálayas is far from certain. It is, however, clear that the trap is younger, since it traverses the granite in several localities, as for instance, north of Niti in Húndés and elsewhere. Whilst it is certain that much of the basic rocks of Húndés and the Himálayas cannot be much older than miocene, nor younger than these deposits, proved by the vast intrusions in the upper part of the middle tertiaries of Húndés, we must go to the Hindu Kúsh and Afghánistán in order to get light thrown on the relations of the granite to the older rocks.

It is certain that the later mesozoic and tertiary epochs saw immense changes taking place in Central Asia.

Changes in the coast-line of the former continents are traceable in the Perso-Afghán area as low down as the upper carboniferous; but not until later cretaceous times those vast overlaps take place which caused the unconformity between the upper cretaceous deposits and tithonian formations. Again, changes of still vaster nature and extent, this time traceable right across from the Caspian to Tibet, took place in upper miocene times. A great part of Central Asia was covered by middle tertiary seas, whilst within the area indicated,

from the shores of the Caspian to Tibet and along the southern margin of the Himálayas, continental conditions prevailed. Although most of the great lines of flexures, which form the Himálayas, the Hindu Kúsh, Saféd Kóh and Alburz must have existed already in palæozoic times, yet the great lateral compressions, which pushed up the enormous masses of the Central Asian plateau with its fringing rims of mountains were evidently formed after the miocene beds were deposited, for we see the latter contorted and crushed, *under a cover of almost horizontal young tertiary deposits*, which so far have suffered little from the slow action of folding, which it may be assumed is still going on.

As I said before, the compression and folding of the Himálayan deposits had been going on probably since palæozic times, and certainly long before the tertiary beds were laid down, yet it may be assumed that during later middle tertiary times this process must have received additional energy; miocene deposits follow in the main the area of distribution of the older rocks, and with the rest of the tertiaries and upper cretaceous form one conformable whole, whilst the principal crushing action is seen to have occurred between the deposition of the miocene and pliocene formations.

It is perfectly conceivable that such folding process may have been accompanied by dislocations and intrusions into the latter of eruptive rocks; indeed this we see to have happened,—basaltic rocks fill up the dislocation of the Húndés plateau, and completely alter the lithological aspect of the older and middle tertiaries.

So far there is nothing to show that the granite in the Himálayas is much younger than the lowest palæozoics, the strata of which it traverses; on the other hand, I shall show later that there are certain points of strong resemblance in the geological histories of both the Himálayas and the Perso-Afghán areas, which point to the possibility of at least some of the intrusive granites of the Himálayas being identical in age with those which are found in such force in the Hindu Kúsh, in the Herát and Kandahár provinces. As the latter traverse upper cretaceous rocks, they cannot be older than that

formation, and they may be even tertiary; it is therefore not quite improbable that the great granite intrusions of the Central Himálayas belong to a period of great secular changes, which possibly endured during all the lower and middle tertiary times, characterized, first, by the appearance of granites in the dislocations which formed and later on by basic rocks, such as the diallages, serpentines and traps.

Against this theory, which as regards the granite is purely conjectural, and based on comparison with neighbouring areas, might be urged the negative evidence, *i.e.*, the absence of granite in any of the sedimentary formations above the older palæozoics (haimantas).

It must, however, be remembered that throughout the belt of sedimentary formations between the Southern range of the Central Himálayas and the line ef the Húndés watershed, no intrusive rocks are met with; and this circumstance is probably explained by the assumption that these intrusive rocks have appeared chiefly along lines of great dislocations only, one of which seems to run along the northern slope of the Southern range of the Central Himálayas, whilst the other probably runs parallel and near the northern margin of the Húndés plain. The belt of sedimentary strata which is bounded by these two dislocations represents, of course, a once much wider area, now compressed into a most complicated system of flexures, forming one solid block of strata, in which only local, though occasionally very extensive faults are met with. The great southern system of dislocations in which the granites appear affects chiefly the older metamorphic and the schistose (vaikrita) areas. Hence, as far as I could ascertain, nothing but these strata or the adjoining haimantas are affected by the granite intrusions. The Húndés dislocation has brought the tertiaries in direct contact with the metamorphics of the "Kailás" range, the watershed between the Sutlej and Indus. This dislocation the "traps" and other basic rocks have filled, and have there produced the partial lithological changes in the older tertiaries which Stoliczka also noticed in the Indus area.[1]

[1] Mem. V, pt. III, 337—354.

At present only the age of the trap is certain; that of the granite, in the absence of better proof, I consider as greater and to come in chronological order immediately before the trap, perhaps in late cretaceous times. In that case it would follow that the southern flexures and dislocations are of older date than the northern, as for instance the northern or Tibetan fault-folds. Indeed, this supposition is supported by other evidence, to which I shall refer later on, namely, the fact that fresh folds are being added to the system along its north-western margin.

2. *Haimanta system.*

Distribution.

Between the metamorphic and semi-metamorphic schists (vaikritas) of the southern chain of the Central Himálayas, and the lower silurians, we find a great thickness of strata, which form one of the most important features of the Central Himálayan sections. Although almost entirely destitute of organic remains and partly altered by the granite intrusions, this system is nevertheless so constant in lithological and stuctural characters, that it must be separated from the overlying lower silurians. Between the Nepál frontier and Spiti it forms more or less a continuous belt; it is well developed in the eastern sections, narrows gradually in Garhwál, then widens considerably in Bissahir, and finally in Spiti is seen as a belt of some 10 to 20 miles in width. Some of the highest peaks lie within this belt of semi-altered rocks.

Boundaries.

The boundary between the schists (vaikritas) and gneiss of the metamorphic zone and the distinctly sedimentary beds which form the haimanta system is not very strongly marked; the passage is nearly everywhere gradual. On the other hand, the upper boundary of the system is perfectly distinct; the haimantas are invariably separated from the silurians by a zone of bright red quartz shales, which I have traced from the extreme north-western limit of my area (Spiti) to the frontiers of Nepál. The haimanta system is enclosed conformably between the vaikritas and the silurians.

Previous notice.

In his paper on the Geology of the Himálayas,[1] General R. Strachey describes this complex of strata as the "azoic slate" series, and he gives the geographical distribution of the formation correct in the main outline; at the same time he over-estimates the total thickness of the system very greatly, namely, upwards of 9,000 feet in all. I consider that the total thickness of this system is certainly not more than 4,000 feet at the most.

Stoliczka,[2] in his Memoir on Spiti, identifies certain slates and quartzose strata as lower silurian; but he also suggests that this group might turn out to be the same as Strachey's azoic slates. I have seen Stoliczka's section in Spiti, and have certainly no hesitation in saying that it is so. In Spiti as elsewhere in the Central Himálayas these "slates" underlie conformably the lower silurians, and must be separated from the latter.

Name.

As this system underlies conformably the lower silurians, it may be inferred that the entire cambrians are included within its thickness; the latter however is so great, and it is also very probable that horizons much older than cambrians are represented in it, that it seemed best to comprise the whole system under one name, leaving it to future researches to classify and divide it further. The term "azoic" is inapplicable, as traces of organic remains have been found by me in its upper division; Stoliczka's name Babeh series would ill define it, as under that name some members of the silurians have been included by Stoliczka, and finally therefore I had to think of a new and more convenient name to give to the whole system. The word *haimanta* will express in this memoir all the thickness of strata lying between the crystallines (gneiss and vaikritas) and the lower silurians; with few exceptions, the system lies within the area of perpetual snow, hence the name haimanta, which in Sanskrit signifies snow-covered.

Divisions of the haimanta system.

Throughout the Central Himálayas, as far I have examined them, I found the haimantas most constant both in lithological aspect as well as in thickness. I

[1] Quart. Journ. Geol. Soc., VII, 292-310., 1851.
[2] Mem., Geol. Survey of India., Vol V.

could make out three main divisions within the system, namely:

In descending order;

Silurians.—

Haimantas:
3. Series of quartz shales and slates.
2. Shales and silky phyllites with great thickness of quartzites.
1. Quartzite, generally purple, with great thickness of conglomerate.

Vaikritas and older gneiss . . . . .

1. Division.

The lowest division of the haimantas is seen in perfect sections in the narrow gorge of the Dhauli Ganga above Niti (near the Kharbasiya encamping ground), at Milam, in the sections of Lissar and Byans, in the Nilang sections north of Gangotri, and also in the Upper Pin river valley of Spiti.

In the Dhauli Ganga valley the lower haimantas consist chiefly of purple quartzites in which thick deposits of a coarse conglomerate and breccia are frequent; the latter are mostly made up of rolled and sub-angular fragments of rocks belonging to the crystalline area, and amongst them large boulders of quartzites and gneissose rocks seem to predominate. The matrix in which these boulders are firmly embedded is nearly always a hard, flinty quartz rock, sometimes partially schistose. It is by far one of the most characteristic and easily recognized horizons of the Central Himálayas, and is invariably met with in all haimanta sections which I have seen.

In the Niti sections, and in fact also in most of the others, the matrix is frequently a deep purple quartz rock, in which the lighter coloured boulders of white and grey quartzites and metamorphic rock stand out conspicuously. Identically the same rock may be seen in the Spiti valley, and in very great thickness also in the Jádh Ganga area. In all the eastern sections, from Milam to the Kali river, this purple conglomerate forms an easily recognized horizon amidst the lower beds of the haimanta system.

Boundary with the vaikritas.

The boundary between this system and the crystalline rocks does not seem very sharply defined in the eastern sections; at Milam, for instance, there is seem-

ingly a very gradual passage from the micaceous schist south of that village, into greenish-grey phyllites and talcose schists with garnets of the vaikritas, and finally into the thin-bedded quartzites, shales and conglomerates of the haimantas, and the change is so gradual that a boundary line could not be drawn with anything like accuracy Similar characters prevail in the Bissahir sections, and partially also in the Spiti area; but, on the other hand, at Niti, Goting and Malari the purple quartzites and conglomerates rest directly on thick-bedded granitoid gneiss, and the boundary is much affected by granite intrusions. It is in fact part of the dislocation, along which the granites have appeared,—a gigantic overthrust.

2. Division.

The purple quartzites and conglomerates are in all sections overlaid by a great thickness of greenish-grey phyllites, shales and thicker-bedded quartzites, traversed by many quartz veins. Towards the upper portion of it, reddish-brown or pink quartz shales are intercalated. This division of the system is well seen on the western slopes of the Bamlas heights, north of the Karbasiya gorge, and also in most other sections in the Central Himâlayas, wherever the beds below the silurians are exposed. They resemble lithologically the Simla slates (Infra. Blaini) and the only fossil traces known from this system have been found in shales in this division. None of these organic remains are more than traces. They are—

Crinoid (?) stem impressions.

Bivalve (?) casts and numerous casts of

Bellerophon sp.

The latter occur both in the purplish-pink quartzite and in the shales accompanying it, and rather high up in the sequence of beds of this division.

3. Division.

In all the Central Himalayan sections through the haimantas from the Kali river to the Spiti province, I have invariably found certain beds which constitute the third division. They consist of two zones of very hard quartz shales, the lower of which is formed by densely red and pink quartz shales, which pass upwards into greenish-grey quartzite and shales,

with pink shaly partings, the whole as far as I know quite unfossiliferous. Together these beds are not more than 250 to 500 feet in thickness. They are so constant in lithological character that they form one of the most valuable guides for unravelling these very often extremely difficult sections.

The lower of these two bands is formed by bright red to pink quartz shales, which form a distinct and easily recognized horizon, but are evidently closely connected with the underlying phyllites, between the upper strata of which similar thin bands of red quartz shales appear as, for, instance, near Gweldung, north of Niti. Sometimes some thin limestone bands are intercalated between the quartz shales, but they also are coloured densely red. They pass upwards into thin-bedded whitish green quartz shales and grey quartzite, with which the red shales alternate to a certain extent. These two horizons are never absent from any lower palæozoic section; the passage from the underlying haimanta quartzites into the red shales and the absence of fossils seemed to indicate the desirability of including the red shales with the haimantas, rather than with the overlying lower silurians. In all the figured sections in this memoir, I have indicated this horizon of red shales as 3.

The haimanta system in Spiti.

Long ago Dr. F. Stoliczka[1] described the palæozoic rocks of Spiti and identified certain micaceous slates, quartzites and conglomerates (Babeh series) with General Strachey's azoic rocks of Kumaon. The latter are the haimantas of this memoir, and when I visited the Spiti valley in 1883, I could verify the correctness of Stoliczka's conclusions with regard to the correlation of the haimanta horizon both in Spiti and Kumaon. The boundary between the crystalline rocks of the Babeh pass and the haimanta system is not sharply defined; in fact intrusive granite obscures the actual contact where I have seen it, and left me very much in doubt whether it would not be found that here, as in the easternmost sections, a passage exists between the two rock systems The difference in the dip, mentioned by Stoliczka, of the gneiss of the

[1] Mem, Geol. Surv Ind., Vol. V.

Babeh pass and the haimantas, I believe, does not exist; the crumpling and folding of the strata is so enormous just north of the pass, that a slight variation in the dip of the respective strata is not sufficient to assume unconformability between the two systems.

The haimantas in the Spiti section (see detailed description, Chapter VII), consist of precisely the same rock series which forms this formation in the sections further east and south-east. Stoliczka has correlated also the Babeh series with the Simla section; the metamorphics of the latter area he classes with the lower and middle portion of the Babeh beds, whilst he believes that the infra-Blaini and Simla slates represent the upper beds of the Babeh series.

Oldham[1] recognized amongst the beds of the Babeh series members of his Chukrata series, whilst some of the beds above he identifies with "infra-Krols" of the Simla area. Stoliczka's identification of the Babeh series with the Simla rocks may possibly be correct, at least as regards the lower Babeh series. In the upper part of this system Stoliczka included some members of the upper silurians and even younger palæozoics, which happen to be inclosed within a synclinal of the Babeh rocks. As the "Babeh series" underlies the lowest silurian (with fossils) it will be seen that the Simla rocks below the Krol limestone would become also pre-silurian, or as I call the system in this memoir, haimantas. I consider however this question far from settled; before it is possible to form an accurate opinion on it, much detailed work will have to be done in the area in question, and the Simla rocks will have to be studied in connection, not only with their continuations north-westwards, but also with the haimanta system of the higher Himálayas.

Kashmir.

Lydekker[2] sums up the whole of the lowest palæozoics in his Panjál system, and describes as the lowest portion of it rocks apparently identical with, or at any rate closely resembling some members of Stoliczka's Babeh series, *i.e.*, my haimantas of the Central Himálayas; he also identifies his lowest Panjáls with the lower Blaini bed and Simla slates. It

[1] Rec. XXI, p. 150. [2] Mem. Geo., XXII.

seems therefore that a great thickness of a more or less uniformly developed series of strata extends in several parallel strips from the Nepál frontier to Kashmir.

Southern synclinals.

Between the southern folds of the Himálayas, there are several parallel synclinals. With them this memoir does not deal, but I may mention that as far as I have become acquainted with the rocks forming these synclinals, I believe them to be generally identical with the haimantas north of the Central Himálayas but differing from the latter in lithological characters.

Thickness.

The total thickness of this system is very considerable, and exceeds that of any of the succeeding formations. It can hardly be less than 3,000 and scarcely more than 4,000 feet. It is too extensively crushed and folded (see fig. 10) to admit of a more accurate estimate, and the lower boundary of it, where the beds pass into the underlying vaikrita schists, is too obscure, and is often entirely hidden by gigantic granite intrusions.

3. *Silurian.*

In the sections between the two parallel ranges of the Central Himálayas, the haimanta system invariably passes upwards into a great thickness of beds which have yielded fossils throughout. There is not the slightest break in conformity; the red and greenish shales of the upper haimantas (3 in the figured sections) pass upwards into and alternate with the lowest beds of the silurians which form a system of not less than 1,300 to 1,400 feet in the Niti area, and rather more than 2,000 feet in the easternmost sections. The lithological character of the system is most constant, and I could distinguish two great divisions of it.

In descending order:

Numbers in figured sections.			
5.	Flesh-coloured and brown quartzites with shales	Upper	Silurian.
4.	*Coral* limestone	Lower	

These two divisions form one conformable whole, and pass

gradually from one into the other by alternating beds. The same character distinguishes the silurians in the entire area of the Central Himálayas, in the most widely separated sections, namely, that the predominant rock of the lower silurians is limestone, whereas that of the upper is quartzite.

Lower Silurian (4).

The lithological character of the lower silurian beds is very uniform over the whole of the Central Himálayas; the pink and grey quartz-schist and shales of the upper haimanta system passes gradually into an alternation of dirty-coloured greyish pink quartzite, with shaly calcareous partings, which again develops into a series of grey shaly quartzites, alternating with dark blue to black *Coral* limestone. All the calcareous beds contain fossil traces; in the lowest beds of this division, which is formed almost entirely of limestone and shales, fossil remains are rare, and generally consist only of indistinct casts of *Orthis* and badly preserved *Bellerophon* specimens.

In the upper beds of the lower silurians, and in the dark *Coral* limestone, fossils are very numerous and mostly well preserved. Most of the collections made by General Strachey, Mr. Hughes, and in Spiti by Stoliczka, were derived from the lower division of the silurian. In common with the remainder of my Himálayan fossils, these also await description, which I trust will ere long be completed. This much, however, has already been ascertained that the fauna of the "*Coral* limestone" division (4) is characteristic of the lowest silurians of Europe. We have therefore a distinct horizon here, which defines not only the position of the *Coral* limestone, but also that of the underlying system of "haimantas," which must represent pre-silurian deposits.

Thickness.

The lower silurian is not of very great thickness. In the Niti and Milam districts, I found that its entire thickness amounted to 300 feet only. It appears that this is about the average thickness of the division in almost all the sections which I have examined, where it was in normal position and not much disturbed.

Upper Silurian (5).

The dark *Coral* limestone beds and shales of the lower silurians are conformably overlaid in the Central Himálayas, by a series of strata eminently characteristic for the silurians in this area. Near the contact of the two divisions, the strata forming the latter alternate, so that one may say that the lower silurians, although chiefly calcareous, pass gradually into the upper division, which is almost entirely quartzitic; in the uppermost part of the lower silurians some of the limestone beds are replaced by quartzitic strata, which gradually increase in frequency, till in the lowest portion of the upper division of the silurians, the limestone beds, disappear almost entirely, and the prevailing type of bed is that of a quartzite. The general character of the division may be said to be an alternation of evenly bedded dirty pink to flesh-coloured quartzites, with greyish green friable shales dividing them.

Thickness.

I found the thickness of this division to be from 1,000 to 1,200 feet in the Niti sections, but it attains a much larger development in the sections north-west of the Mána heights and in Spiti.

Fossils.

Traces of organic remains abound in all the beds composing the upper silurians, but they also await determination in common with the remainder of the Himálayan collections.

Spiti.

Stoliczka's work in Spiti constitutes so to speak the first critical examination of the various geological formations of the Central Himálayas. Strachey's researches have reached the scientific world in the form of a short paper only, in which all details had been avoided. It therefore happened that the Spiti sections, as far as known, became type sections, and the stratigraphical nomenclature adopted by Stoliczka was afterwards introduced into later writings on Himálayan geology, as for instance Lydekker's "Cashmir." This is to be regretted for Stoliczka's work of one season was naturally fragmentary, and his classification of formations partly based on wrong data.

He divided the pre-carboniferous rocks into 1. Babeh series, 2. Muth series; the first represents, according to Stoliczka, the lower and upper silurians, whereas the second series he places doubtfully amongst the silurians. Had he devoted more time to this most difficult ground, or had he been able to study the same formation in a more accessible section, he would have seen that these divisions were incorrect. The Babeh series embraces the whole of what I have termed haimanta system, and the greater part of the lower silurians in some sections. But the Muth series I found to be partly silurian and partly (the Muth quartzite) carboniferous. The full details of the case will be found in my chapter on Spiti. To adopt, therefore, Stoliczka's nomenclature would only perpetuate an error; most of the horizons in Spiti can easily be identified both by their lithological character as well as their fossil contents with corresponding horizons in the Niti area, and these again with horizons in Europe, so that the necessity of adopting local nomenclature disappears.

Stoliczka's divisions of silurians.

The silurians are sharply defined also in Spiti; they are inclosed conformably between the red quartz shales (3) of the haimanta system, and the dark *Coral* limestone of devonian or lower carboniferous age. Here also I could distinguish two well defined divisions, namely, (1) *Coral* limestone with lower silurian fossils; (2) pink and brown quartzites alternating with greenish grey shales, with few fossils, mostly upper silurian types.

Sharply defined in Spiti.

The only instances of contemporaneous igneous rocks within the silurians seem to be found in the Spiti area; I have not seen these rocks, but Stoliczka has noticed the same (*p.* 20). They are apparently entirely wanting in the eastern sections.

Interbedded traps.

4. *Upper Palaeozoic systems: Devonian and Carboniferous.*

Between the dirty pink and brown quartzites of the upper silurians (5) and the *Otoceras* beds (10) of the lower trias, a great system of rock formations is found in the Central Himálayas which in age must range from the lower devonian to upper carboniferous.

This group of formations I divide into—

Number in sections.			
8.	White quartzite with limestone .	. Upper	Carboniferous.
7	Red *Crinoid* limestone . .	. Lower	
6.	Dark *Coral* limestone . .	. Devonian?	

(6) Dark *Coral* limestone devonian?

There is no break between the strata of the upper silurians and the overlying formations in the Central Himálayas. The quartzites of the former are frequently replaced by dark limestone beds near the upper limits of the silurians, and even are seen to alternate with the dark limestone above, and finally become completely replaced by the latter, till the whole is seen to be a limestone formation only, in which here and there a dirty pink quartzite bed is intercalated. A sharp line, where silurian ends and the overlying system begins, can therefore not be drawn, but the lithological character of the mass of the latter is so distinct from the upper silurians that it would have to be separated, even if the traces of fossils found in it would not necessitate doing such.

The prevailing rock of this system (6) is a very dark grey, or black limestone in even beds, which are sometimes flaggy, but generally concretionary, and present then the characteristic contact between the strata which in sections may be likened to intricate lines of suture, the beds being as it were closely *knitted* together. White calcspar veins traverse the system in every direction, and on the fractured surfaces, sections of fossils, chiefly *Corals* and *Brachiopods*, appear in large numbers, together with fragments of *Crinoids*. But very few of these remains can be identified specifically.

Towards the upper part of the system, some thin partings of calcareous shales divide the limestone strata; also red and brown thin-bedded *Crinoid* limestone of earthy texture appears, and is intercalated with the dark *Coral* limestone (6) till the system gradually becomes a series of light bluish grey earthy limestone beds, with brownish red beds alternating, both containing *Crinoid* fragments.

The total thickness of this formation I found to be about 650 to

Thickness and distribution.

700 feet in the sections of the Niti district, but both in the Milam and Dharma valleys it swells out to very much larger proportions. In the palæozoic series of the Lipú Lék and other localities of the Byans district, these dark *Crinoid* and *Coral* limestones play an important part and are developed in great thickness, but the beds have suffered such crushing and folding that to measure their thickness correctly would have been a hopeless task. Nevertheless I think that there this concretionary *Coral* limestone can hardly be less than 1,000 feet in thickness. It yielded better fossils also, and these await determination.

I also met with it in great thickness in the Spiti area, south of Muth, and on both sides of the valley. Stoliczka has quite overlooked this limestone formation I believe. On pages 21 to 24 of his memoir he describes certain rocks of the "Muth series," of which the second only is silurian, which according to him is overlaid by the white quartzite, a horizon which is undoubtedly upper carboniferous. Had he moved along, or near the crest of the mountain range, which forms the left side of the valley south of Muth, he would easily have been able to make out the succession of the entire series which constitute the palæozoic group in Spiti.

The *Coral* limestone (6) may also be seen in great force in the area between Nilang and the Sutlej, especially well in the valley of the Hóp Gádh, or rather as forming the steep sides to it which lead to the Tsang-Tsok Lá (pass) (see pl. 11).

Carboniferous.

All the strata which rest conformably on the dark *Coral* limestone (6) and are overlaid by the *Productus* shales (9) must be considered carboniferous. This system forms one of the most important features in all Central Himálayan sections, alike on account of its thickness and uniform distribution, and by reason of its characteristic lithological development.

Divisions of the carboniferous system.

Of the full original development of the system I have no certain data; the *Productus* shales (9) rest on a partially eroded surface of the carboniferous, and until it is possible to compare the sections of the Central Himálayas

with neighbouring ones, which are undoubtedly normal, it would be premature to say whether the sections in Spiti which seem more fully developed than the carboniferous elsewhere in the Central Himálayas are complete in that respect or not.

At present I found that the carboniferous system consists of the following divisions in descending order :—

Number in the figured sections.		
8*a*.	Dark limestone with *Productus* sp. only seen in Spiti.	Upper carboniferous.
8.	White quartzite	Upper carboniferous.
7.	Red *Crinoid* limestone	Lower carboniferous.

(7) Red *Crinoid* limestone.

I adopted this term during my first season's work in the Himálayas, a red *Crinoid* limestone forming the most characteristic portion of the division. Later on when I found that the horizon is a most constant one throughout the Central Himálayas, and that the brownish red earthy limestone remains lithologically the same over the whole area, I allowed the term to stand.

There is no sharp boundary between the underlying devonian *Coral* limestone (6) and this division. Earthy, dark grey, or brownish red limestones, mostly thinly stratified but always yielding *Encrinite* fragments, are intercalated between the *Coral* limestone near its upper limit, gradually increasing in frequency, and finally the formation becomes entirely a *Crinoid* limestone, which I distinguish in map and section as division (7) of the lower carboniferous. In the easternmost sections of the Upper Dharma valley, near the head of the Kali river (in Byans) and at the Lipú Lék pass, the intercalated beds are generally light bluish grey earthy limestone, which swells out into a division, not less than about 600 to 700 feet thick, and is followed by densely red brown and red earthy limestone, of about the same thickness, both formations containing, besides other fossils in poor preservation, many *Crinoid* fragments.

In the Painkanda sections the bluish grey limestone beds at the base of this division are entirely wanting; the red *Crinoid* limestone rests directly on the *Coral* limestone (6).

In the Nilang area and Spiti, the bluish-grey limestones are again more strongly developed, and the lower division of the carboniferous is consequently of greater thickness there. In all sections, however, the red *Crinoid* limestone is present, and lithologically identical throughout; I think its total thickness anywhere does not exceed 400 to 600 feet.

Fossils.

The fossils found in this division are in a very poor state of preservation. Casts of *Brachiopods*, *Orthoceras* and *Crinoid* remains may be said to be the sum total of what has been found in these earthy limestones.

White quartzite (8).

The red *Crinoid* limestone is overlaid by a very characteristic horizon, namely, the white quartzite (8). It is generally a fine grained, hard, pure white quartzite, in thick beds; its uppermost beds are often a fine grit, or quartz sandstone with a few shaly beds dividing it. Near its base I noticed in some sections, though rarely, that beds of red *Crinoid* limestone are intercalated between the quartzite. I found that the total thickness of this division ranges from 350 feet (in Niti) to about 800 in Spiti, where it is particularly well developed. Fossils are scarce in this division of the carboniferous or generally seen only on the weather-worn surfaces; they are so closely united with the rock in which they are contained that it is almost impossible to extract them. *Brachiopods*, *Orthoceras* sp. and *Corals* are seen weathered out on the surface of the rock.

Thickness.

Fossils.

Distribution.

I found this division of the carboniferous system in the Niti sections when I first visited that ground in 1879; it is there partly eroded, and the succeeding *Productus* shales (9) rest directly on red *Crinoid* limestone in several sections. It forms one of the most constant features in almost every one of the sections south-east of Niti as far as the Nepál frontier. Partially eroded the thickness of the white quartzite varies greatly and often suddenly. But nevertheless it is scarcely ever quite absent.

North-west of Niti, in the Nilang area it is also present, directly

overlaid by the *Productus* shales; but east of Nilang in Spiti, evidences of its erosion in permian times are wanting. There the carboniferous system is very well seen in the fine cliffs near Muth, as shown in the profile pl. 4, which is the view taken from the opposite heights on the right side of the valley. The white quartzite (8) is overlaid in Spiti by flaggy, dark grey, to blue limestone beds, which alternate to some extent with the quartzite below. These hard splintery limestones, almost dolomitic in character, have a total thickness of only 50 to 70 feet, but yielded abundantly *Athyris royssii*, *Productus sp.*, etc. Whereas they show by partial interstratification with the white quartzite that they clearly belong to the underlying division (8), they end abruptly above, being overlaid by the dark crumbling shales (9) which are probably of permian age. I have not met these limestones in any other section in the Central Himálayas, but whether I may look upon this division as the last deposits of the carboniferous system or not in the Himálayas is not possible to say, owing to the fact that large tracts of what are now the Central Himálayas have been partially eroded by the early permian seas, and successive strata of the upper carboniferous are overlapped by the permian *Productus* beds (9).

Limestone above the quartzite 8*a*.

There are evidences, both stratigraphical and lithological that considerable physical changes had taken place near the close of the carboniferous period. Not only is the lithological change from the fine grained white quartzite of the upper carboniferous to the crumbling black shales of the *Productus* horizon (9), such as to necessitate the supposition that radical changes must have occurred in the outlines of the coast, near which the black shales surely must have been deposited, but also the latter are found to overlap the several stages of the carboniferous in the different sections of the Central Himálayas thus clearly demonstrating the fact that after the deposition of the uppermost carboniferous, the distribution of land and water must have suffered considerable alterations. At the same time in the Niti area

Physical changes near close of the upper carboniferous.

at all events one would scarcely conclude from a cursory examination of the fossils contained in the black *Productus* shales (9), that the break between the upper carboniferous and the former could have been of very great extent as regards time; the black shales (9) yield forms which might be upper carboniferous quite as well as permian, though structurally they belong to the overlying system of strata.

Wide extent of carboniferous deposits.

There is perhaps no other formation in Asia which has a wider area of distribution than the carboniferous; we know that it is found throughout the entire length of the Himálayas, and as far distant as in Kashmir scarcely differs in lithological character, nor in the peculiar fauna it contains.

I myself have proved its existence in the hill ranges (Síáh-Kóh) east of Kábul, have met with carboniferous beds in the Hindu Kúsh and north of it, and seen it well developed in the mountain ranges east and south-west of Herát, and again further west where carboniferous rocks play an important stratigraphical rôle in North-Eastern Persia. We know the same rocks extend throughout Northern Persia into Armenia and the adjoining countries. In Central Asia[1] and China[2] it is well represented.

Both in North-Eastern Persia and in Áfghánistán I found evidences which also show that there, as in the Himálayas, the close of the carboniferous witnessed marked physical changes. The purely marine deposits of the carboniferous I found followed by a mighty system of beds, which in a large measure are littoral; the beds immediately following the carboniferous in those areas are conglomerates, and plant-bearing (carbonaceous) sandstones and shales, which have reminded me, when I first saw them, of our Indian lower Gondwanas (Talchirs, &c.[3]).

Evidently the changes which took place near the close of the carboniferous were of a very wide-spread nature; and if it required proof that the great wrinkling process, which resulted in the elevation of the Himálayas, did not begin in young tertiary times, but rather

[1] Mushketoff, Turkistán. [2] Richthofen, F.—China
[3] Rec. Geol. Surv. Ind., Vol. XVIII, p. 62; XIX, pp. 49, 57, 242; XX, p. 98.

was continued up to that time, and even prolonged after it, the "break" after upper carboniferous times must needs be strong evidence that even in palæozoic times, at least, the main outlines of the Himálayas must have been fore-shadowed, and that even then the ancient coast-line could not have been very far removed from the present limits of the Indian Himálayas; on the other hand, comparatively slight changes of elevation, produced by lateral compression (folding), could produce extensive overlap, without having to assume for this phenomenon equally extensive periods of time, which are precluded by the near relationship of the faunas in the overlapped and the overlapping formations of the Central Himálayas.

CHAPTER IV.—STRATIGRAPHICAL FEATURES—*continued.*

PERMIAN AND MESOZOIC GROUP; TERTIARIES AND RECENT FORMATIONS.

5. Permian and 6. Trias Group.

In the preceding pages I have briefly described the members of the palæozoic group, and have endeavoured to show the striking continuity which exists between the various systems constituting it. From the semi-metamorphic schists, the vaikritas, at the base of the haimanta system to the upper carboniferous, we see one unbroken succession of beds conformable to each other, each division passing gradually into the next higher one. It points to an immense era of tranquillity during which deposit on deposit of the palæozoic were laid down with their organic remains, and during which the only physical changes of importance took place near or at the close of the carboniferous period, changes which resulted in an overlap of dark shales, probably permian, over the divisions of the carboniferous in succession.

With this unconformity another great group of deposits begin which range from the permian *Productus* shales, (9) to liassic limestones above; within this mighty group there is not the slightest unconformity or break visible, and no geologist who had once seen these sections could doubt for a single moment where the line should be drawn between the two great groups,—the palæozoic and the

following deposits. This line could nowhere be drawn, except at the unconformity between the carboniferous and the *Productus* shales; from the latter deposits to the liassic limestones above it is one unbroken chain of deposits, passing one into the other by gradual lithological changes.

Considered from both a lithological and palæontological point of view, this group of strata may be divided into the following systems or divisions in descending order:—

Numbers in figured sections.	Divisions.	Systems.	
16		Lias.	
15	*Lithodendron* limestone	Rhætic.	
14	Dolomites . . .		
13	*Modiola* beds . .	Upper	
12	*Daonella* ,, . .		Trias.
11	*Ptychites Gerardi* zone	Lower	
10	*Otoceras* ,,		
9	*Productus* shales	Per	

5. *Permian, Productus shales* (9).

At once almost the most insignificant in thickness and the most easily recognized lithologically, this horizon forms one of the most important landmarks in the structure of the Central Himálayas. Generally resting on the white quartzite (8) of the upper carboniferous, it sharply contrasts with the latter; consists of very dark, occasionally micaceous shales, exceedingly friable and crumbling into an earthy dark mass. The shales may be said to be carbonaceous here and there, with coaly traces,—carbonized vegetable matter. A few irregular partings of hard ferruginous sandstone divide the thickness of shales; an occasional string of nodular clay iron ore is found in place of such sandstone partings. In lithological character these shales differ so little from the next higher horizon, that it is easy to mistake one for the other. The higher *Otoceras* beds are, however, less earthy and not

micaceous. Throughout the horizon fossils are found,—chiefly *Producti* of latest carboniferous or permian type. The best preserved specimens are contained in the grey sandstone partings which are often crowded with *Producti*.

Stoliczka noticed these beds, which, amongst other localities, are also well developed at Kuling in the Spiti valley, and he named the horizon in consequence the Kuling shales. But he did not notice that only about one-half of the thickness of these dark shales have yielded *Brachiopods* of later palæozoic type, and that some very dark shales above, which are also well seen at Kuling, really belong to the lower trias, which he considered altogether absent in the Spiti area. I feel therefore that the retention of the term Kuling beds for this horizon would be misleading, as the entire thickness of the Kuling shales of Stoliczka certainly does not belong to the carboniferous system.

I have seen specimens of the "Kuling shales" of Kashmir, which show that identically the same rock extends far to the north-westwards of the Central Himálayas.

Thickness.

In normal sections the total thickness of this division varies from 120 to 250 feet, but being a soft and easily disturbed deposit, it has suffered very largely from crushing and folding. The more rigid strata of the triassic system have often been pushed over the carboniferous beds, during which process the soft *Productus* shales have naturally suffered most. On such occasions, in fact, the dark shales have acted the part of a lubricator between the rigid strata of the carboniferous and trias, themselves being crushed and distorted, whilst the trias block was pushed over the carboniferous formations. The same phenomenon may be observed frequently in all disturbed areas where soft shales divide systems of more rigid nature, such as hard limestones, etc.

6. *Triassic System.*

Passage into beds above.

Although sharply and abruptly defined at its base in all the sections which I have examined, the dark *Productus* shales may be said to pass gradually up into the

lower trias through a series of strata which I might call passage deposits, which contain a fauna exhibiting strong affinities both with permian and triassic forms. This is the *Otoceras* horizon.

Trias.

The strata of the triassic system take perhaps the largest share in the mountain structure of the Central Himálayas. The greater part of the Northern Range of the Central Himálayas, in fact nearly the whole of the watershed range between Húndés and the Bhót Maháls of Garhwál and Kumaun, is formed of triassic rocks.

From the Nepál frontier to Spiti, an enomous development of triassic limestone, dolomite and shales rests conformably on the *Productus* shales (9) which pass upwards into the lower trias, and together with these shales the trias forms a closely connected structural system. The distribution of this complex of strata follows closely that of the palæozoic group; frequently the members of the triassic system form long and narrow strips inclosed in synclinals of carboniferous rocks, a structure which is especially clearly seen in the Bhót Maháls of Kumaun, where these synclinals are often remarkably narrow troughs (see pls. 15 and 16). The upper trias, with rhætic above, generally forms precipitous scarps towards the south, often quite inaccessible.

From afar off the trias and rhætics may be distinguished from other formations by the yellow ochre colour into which they weather, which strongly contrasts with the dark tints of the lower palæozoic and red and white colours of the carboniferous beds.

Thickness.

The total thickness of the entire series is about 4,000 feet in the Niti sections, but probably exceeds that figure in the area further eastwards, where the upper trias and rhætic deposits swell out considerably.

Divisions.

In the following pages I have given the main divisions into which the trias of the Central Himálayas may be divided, and I have in that list adopted the numbers for the various divisions, which are used in my figured sections. With few exceptions the various horizons of the trias may be followed up

throughout the length of the area described here; in most cases the lithological character of the beds composing these horizons remains remarkably uniform.

On the whole a great likeness exists between the trias and rhætic of the Himálayas and the Alpine type of these systems; a feature which had long ago been recognised by Salter,[1] Strachey,[2] and Eduard Suess,[3] and enough fossils have been obtained from the different divisions to enable us to compare the trias of the Himálayas with that of the Eastern Alps.

I distinguished the following divisions and zones in the trias sections of the Himalayas.

System.	Numbers in sections.	Lithological character of divisions.	Zones of	In Germany.
UPPER TRIAS.	13	6. Liver-coloured limestone with greenish grey shales in the Niti area; strong limestones in other localities.	*Corbis sp.* . .	Keuper.
		5. Friable shales and earthy beds in Niti; limestone and shales in Spiti, Niiang and the eastern sections.	*Spirifer lilangensis Stol.*	
	12	4. Limestone	*Tropites sp.*	
		3. Earthy limestone and shales .	......	
		2. Black limestone flags and dolomites.	*Daonella sp.*	
		1. Black limestone flags with partings of splintery black shales.	*Brachiopods.*	

[1] Palæont. of Niti 8°, Calc., 1865.
[2] Quart. Journ. Geol. Soc., X (1854).
[3] Verh. Geol. Reichsanst., XII, 1862, p. 258.

System.	Numbers in sections.	Lithological character of divisions.	Zones of	In Germany.
LOWER TRIAS.	11	4. Hard grey concretionary limestone in thick beds.	*Phychites gerardi Bfd*	Muschelkalk.
		3. Earthy limestone . . .	*Rhynchonella semiplecta Mun. Var.*	
	10	2. Limestone alternating with shales.	*Posidonomya sp.*	Buntsandstein
		1. Dark shales with limestone partings.	*Otoceras woodwardi.*	

Lower trias.

The most marked feature in all the triassic sections which I have examined is the structural and lithological continuity which exists between the *Productus* shales and the lowest trias beds. Whilst the former are not only sharply separated from the underlying carboniferous in lithological character but overlap the same also, they form a continuous series of beds with the overlying trias. In spite of lithological differences between the various beds which compose the permo-trias-rhætic group, there is a certain character common to all the divisions. Shales, limestones and dolomites all weather a deep sienna tint, whilst the beds successively pass one into the other, or show their close relationship by frequent alternations. There is scarcely any variation in the character and composition of the lower trias in any of the sections which I surveyed. Practically from the most eastern sections, those of Byans to Spiti, west of the Sutlej, the succession of beds remains the same. In all of them the lower trias beds with the underlying *Productus* shales are present.

Stoliczka during his brief examination of Spiti fell into the error of assuming that the upper part of the lower trias, the limestone with *Ptychites gerardi*, rests immediately on the carboniferous Kuling shales, and that therefore the lowest trias, corresponding to the

Bunter in Germany or the Werfen beds of the Alps, is entirely wanting in the Himálayas. The beds with *Otoceras* are certainly not of very great thickness and differ lithologically scarcely from the still lower *Productus* shales, but still it is rather surprising how such a careful observer could have missed finding some of the very numerous fossils in the beds immediately above the *Otoceras* stratum, and below the "Muschelkalk" horizon. At Kuling itself these beds are well developed, and have yielded fossils identical with those found in the magnificent Niti sections. To obviate repetitions, I must refer the reader to the detailed description of the Niti sections for further information regarding the different beds which constitute the division of the lower trias, and content myself here with a few words only. I found that immediately above the *Productus* shales (9) which I look upon as permian, a small thickness of dark limestone with splintery shales contains such forms as *Otoceras woodwardi. sp.*, *Xenodiscus buchianus*, *X. demissus*, *X. gangeticus*, etc., etc., which shales I look upon as passage beds from the permian into the upper beds of this sub-division, which contains fossils of more pronounced triassic type, such as *Monophyllites*, *Norites*, etc., and finally passes into earthy thin-bedded limestone with *Brachiopods* of triassic type.

The stage, which has yielded the curious forms of partly triassic, partly permian type, and which forms no doubt true passage deposits may be looked upon as a horizon of the trias still lower than the Werfen beds of the Alps, and considerably lower than what is understood now as "Bunter." This accords with the finds in other parts of the world; forms closely allied, if not identical with *Otoceras* have been found by Von Abich in Armenia, and latterly beds lower than the Werfen horizon, and probably above the upper permian in age have been discovered in Sicily.

Rhynchonella semiplecta zone.

Near the uppermost horizon of this series, the limestone beds become generally much more earthy in character and *Cephalopods* scarcer; a poor *Brachiopod* fauna of Muschelkalk type is all which I have hitherto found in this zone. The zone is present in all lower trias sections, but

Müschelkalk.

seems to be closely connected with the beds above, which are grey, concretionary, generally very hard limestones, containing a purely Muschelkalk fauna. Stoliczka has correctly identified the horizon in Spiti and described a number of fossils from it. This division may be looked upon as the upper part of the lower trias; the demarcation between it and the succeeding strata is very slight, as regards the lithological character of the two divisions, but on the other hand, the next succeeding division is well characterized by a peculiarly upper trias fauna.

Upper trias.

In the Spiti and the eastern sections (Dharma, Lissar, etc.), the upper trias forms one continuous limestone and dolomite series, only parted by calcareous shales, whilst in the Niti and Milam sections great thicknesses of friable shales come in near the upper half of the series, which have yielded fragments of vegetable matter. Generally speaking, the lower half of the upper trias is developed mostly as a series of very dark, almost black, hard limestones with partings of shales; this sub-division may be seen in all triassic sections of the Himálayas, and forms one of the most characteristic horizons; *Daonella sp.* and true upper trias *Cephalopods* (Hallstadt types) are found in these lower beds.

The upper beds show more variation. Chiefly shaly in the Niti and Milam areas, they are represented by strong limestones in Spiti and in Dharma. Fossils are rarer in this horizon, which is also often inaccessible, as it generally forms precipitous cliffs. But enough of fossil remains have been found in beds of this division to allow local identification of the horizon where seen.

Neither in this grand series of trias beds, nor in the succeeding rhætic has any unconformity been detected, but rather a gradual passage from one into the other sub-division may be observed.

7. *Rhætic and Lias.*

Rhaetic and lias.

From the north-western corner of the ground here reported on, namely, the Spiti valley, to the frontier of Nepál, I found the upper trias regularly and conformably overlaid by great thicknesses of limestones and dolomites, of

which the lower and greatest portion of it belongs to the rhaetic system, whilst only the shell limestones which cap these strata can be identified as lias and that of an Alpine facies.

The general succession of these two systems I found to be almost uniformly the same in all the sections which I have examined. It is in descending order:

Systems.		Number in sections.	Lithological character of divisions.	Zones of	Alpine equivalents.
Lias		16	Black shales, and dark earthy limestones, with oolitic structure.	Contain lower lias remains.	Gresten beds.
UPPER RHÆTIC.	Passage beds.		Grey *Crinoid* limestone in irregular thin beds.	*Terebratula horia Sss. Gervillia inflata Schfh.*	Starhemberg facies of the Kössen beds.
		15	*Lithodendron* limestone in thick beds, with a lower "Kössen" horizon.	*Lithodendron* . .	*Lithodendron* limestone.
LOWER RHÆTIC.			Great thickness of limestone and dolomites.	*Megalodon sp.* . .	Dachstein limestone.
		14	Great thickness of dolomites; great thickness of flaggy dark limestones, with thick-bedded dolomites which gradually pass downwards into the upper trias.	*Lithodendron* . .	Haupt dolomite.

Distribution.

Rhætic and liassic limestones cover a very large area in the higher Himálayas and follow generally the limits of the distribution of the trias, in fact usually cap the latter, presenting gigantic scarps towards the south, with a dip-slope gradually falling towards the north where the complex of rhætic-lias beds is overlaid by jurassic Spiti shales. Excepting where ravines have cut through these immense blocks of rhætics, the greater part of this system forms inaccessible precipices, but

enough traverses could be made in the various parts of the Central Himálayas to show how very uniformly the sub-divisions are developed.

Thickness.

The total thickness of the rhætic with what remains of the lias is about 2,000 to 2,500 feet, though it may exceed that in the Spiti area.

Alpine equivalents.

Whilst the lowest members of trias in the Himálayas are widely divergent from anything seen in the Alps, it seems as if the similarity between the triassic and rhætic formations in the Central Himálayan and Alpine regions increases as one ascends in the group, until the rhætic formations are reached, which apparently are almost identical with the Alpine rhætics, not only in their fossil contents but also in lithological character.

Passage beds.

There is not a sharply defined line between the limestones which I consider rhætic and the genuine lias beds; grey *Crinoid* limestones in irregular thin layers, and yielding numerous small *Bivalves* occur in between massive deposits of the rhætic *Lithodendron* limestone, and these *Crinoid* limestones containing as they do *Brachiopods* of Upper Kössen facies must be considered as passage beds into the true lias.

Lias.

The uppermost beds (16) of the series consist of dark earthy and bituminous limestones; the fossil remains which I have found in them are much too indistinct to allow close comparisons, but Stoliczka was fortunate enough to find several good Alpine lias forms in this horizon, which is widely distributed over the Central Himálayas. By itself, however, the thickness of this liassic horizon is inconsiderable and probably does not exceed a hundred feet in any of the sections.

Stoliczka included all the massive limestones of the upper rhætic above the beds with *Megalodon* with the lias (Tagling), but this I am decidedly not inclined to follow. The *Lithodendron* limestone is intimately connected with the underlying *Megalodon* beds and undoubtedly belongs to that series of strata.

8. Jurassic deposits; Spiti shales (17).

Probably the widest known amongst the Himálayan formations are the beds out of which the numerous and well-preserved jurassic fossils have been collected, not only by geologists and European travellers, but by natives both of Tibet and India. From ancient times a trade in jurassic *Ammonites* has existed; great quantities of these fossils are brought every year to India, chiefly to the holy places of Hindu pilgrimage, and sold as relics to Hindu worshippers. Long before the localities from whence these fossils came were known to geologists, some of the remains were described and figured)[1]. But not till later on, when the brothers Strachey explored the higher Himálayas, did the jurassic deposits become known. Afterwards the visits to Spiti by Theobald, and the explorations by Stoliczka, resulted in a closer study of the jurassic formations. Stoliczka comprised the whole of these deposits under the name of the "Spiti" shales, and as this formation is remarkably constant in lithological character, over a very large area of the Central Himálayas, the name is understood to define the entire thickness of jurassic deposits.

The system consists chiefly of shales and is well defined between the liassic limestones (16) and the greenish sandstones (Gieumal sandstone) of the cretaceous system.

Apparently the Spiti shales rest perfectly conformably on the beds with liassic fossils, and the only evidence of a break in the continuity of the formations is the complete and absolute change of lithological character as one passes from the earthy limestone of the lias to the dark crumbling Spiti shales. Additional evidence in favour of the supposition that there exists a break between the lias and jurassic deposits of the Himálayas is afforded by the fact that a sudden change of fauna sets in with the Spiti shales. On beds with liassic forms rest, as far as we know at present, strata which contain organic remains of middle and upper jurassic types.

The upper boundary seems less sharply defined; there the shale

[1] Trans. As. Soc. Beng., Pt. II, XVIII.

formation passes gradually into a formation of shaly greenish sandstone, which may be of lower cretaceous age.

The so-called "Spiti shales," which are thus limited in both directions, represents, as far as it is possible to say at present without having compared the fossil contents, the entire middle and upper jurassic system. The lower jurassics are doubtful.

There are several horizons of dark shales found in the Central Himálayas belonging to widely separated geological systems, but nevertheless it is never difficult to distinguish the jurassic Spiti shales amongst them. Stoliczka has already given an excellent description of this system in his "Memoir" to which I have little to add. But as I have seen the formation in the Niti area and in Húndés, where the beds forming it are seldom much disturbed, I have been able to distinguish at least three divisions of the system.

In descending order follows :—

c. Grey shales with occasional sandstone bed.

b. Friable dark shales with concretions containing many fossils.

a. Dark splintery shales, fossils rare with brown earthy shales at the base.

a. In most sections through the Spiti shales, I observed a small thickness of rusty brown earthy shales at the base of the jurassic deposits, and immediately above the liassic limestone. Stoliczka has made mention of it in his Memoir (page 83). Only traces of fossils have been obtained from it, mostly *Belemnites*, and it is possible that this horizon may be found to represent part of the lowest jurassics. In the Shal-shal sections, north-east of the Niti area, this horizon may be distinctly seen.

It is overlaid by black splintery shales, occasionally micaceous, and with rust-coloured ferruginous blotches on their fractured surfaces. The shales are very friable and decompose into a clayey mass. Nodules of iron-pyrites are common in this as in the higher beds of the Spiti shales. Calcareous concretions are found scattered throughout this horizon, and they nearly always contain some fossil, though

in this lower portion of the Spiti shales, the fossil remains are less well preserved, and often crumble altogether into small fragments.

b. The middle horizon of the Spiti shales is similar in lithological character. Fine, splintery black shales, with many ferruginous partings and marly concretions which generally yield well-preserved fossils, especially *Ammonites*. From this level nearly all the "Spiti shale" fossils have been derived. This horizon passes upwards into—

c. Also chiefly consisting of black splintery shales, but with fewer concretions, and frequently alternating near the top with more regularly bedded black shales and impure limestone. *Ammonites* become scarcer in this horizon in Niti, whilst *Belemnites* and *Bivalves* predominate. Towards the upper part of this horizon, beds of lighter coloured sandstone in thinner beds are intercalated, and it appears that the Spiti shale formation passes into a series of argillaceous shales and limestones which I have in this memoir included in the cretaceous system.

The strata of the Spiti shales being generally soft are easily disintegrated, and have readily yielded to the crushing and folding process to which the Himálayan systems were and are still subjected. The Spiti shales therefore not only take part in all the grand flexures, but, as is invariably the case where rigid strata alternate with more yielding ones, they have been frequently squeezed into the narrowest folds, and often the rigid cretaceous strata overlying the Spiti shales have been pushed over the latter. Very much disturbed sections of this nature may be seen in the Dharma and Lissar valleys, where all that remains of the Spiti shales are very narrow strips inclosed in crushed folds of the rhætic and lias.

The fossils found in this system have so far shown an upper rather than middle jurassic character; but as most of the material has been derived from the middle and upper division (b and c) of the system, it is quite possible that not only the middle, but also lower jurassics may eventually be discovered in the Himálayas.

Distribution. Hándés and Central Himálayas.

The jurassic deposits form one of the most widely distributed systems in Central Asia. Wherever I have met them in the Central Himálayas, they presented

the same lithological characters. From the Upper Lissar valley in Eastern Kumaun, to North-Western Spiti, they have been traced in patches which are preserved in synclinals of rhætic and lias beds.

Zanskár and Kashmir.

Stoliczka's observations show that the Spiti shales occupy a wide range from the Spiti valley to Zanskár and beyond, where he has found them north of the Karakorum pass.

Hazára and Sulaimán range. Khorassán and Turkistán.

The upper jurassic strata of Hazára have also been identified with the Spiti shales of the Himálayas, and I believe that an upper jurassic horizon, scarcely differing if at all in lithological character, will be found to underlie the lower cretaceous in all the sections through the latter system in the North-Western Frontier districts. In the Sulaimán range, dark shales with calcareous concretions occur which strongly reminded me of the Spiti shales.[1] They are immediately overlaid, or pass into grey marly shales with badly preserved *Ammonites;* the whole being conformably overlaid by the lower cretaceous sandstones of the Takht-i-Sulaimán.

Later on, I had an opportunity of studying the sections north of the Hindu Kúsh and in Khorassán, and in both found a great thickness of dark crumbling alum shales, which are conformably overlaid by red and brown coarse sandstone and grits (my "red grit group" of former papers) of neocomian age. This is, in fact, the Sulaimán section with very slight lithological differences. It is known that the same succession of black crumbling shales with jurassic fossils, overlaid by neocomian sandstone, runs through the entire north of Persia, and is again met with near the shores of the Caspian, forming one of the most constant of geological horizons.

There is, however, one feature, which distinguishes the true Spiti shales from the dark alum shales of Khorassán and Turkistán, namely this: the Spiti shales are essentially a marine formation, containing as far as known nothing but a marine fauna, whereas the alum shales of the Afghán-Persian area are nearly entirely a littoral formation, as

[1] Records, XVII, p. 184.

the mixture of marine forms (*Brachiopods*, etc.) with the remains of land plants clearly shows.

9. Cretaceous group.

Only in the sections of Húndés north of the Niti pass, and the passes which lead from Húndés to Milam, did I observe beds younger than the jurassic Spiti shales. The range which forms the watershed between the Ganges drainage and the Sutlej, in that region, and over which several easy passes lead into Húndés, as for instance the Ma Rhi La (16,380′), Shal-Shal pass (16,390′), the Balch Dhura (17,590′), etc., consists chiefly of a series of strata which rest conformably on the Spiti shales, and though the passage from the latter into the former appears gradual to some extent, yet the character of the beds is so different from the Spiti shales that it is easy to draw the boundaries even at a great distance. I met the rock first in the sections north-east of the Niti pass, in the lower reaches of the Sirkia river near the Tibetan town of Dongpú; see fig. 11.

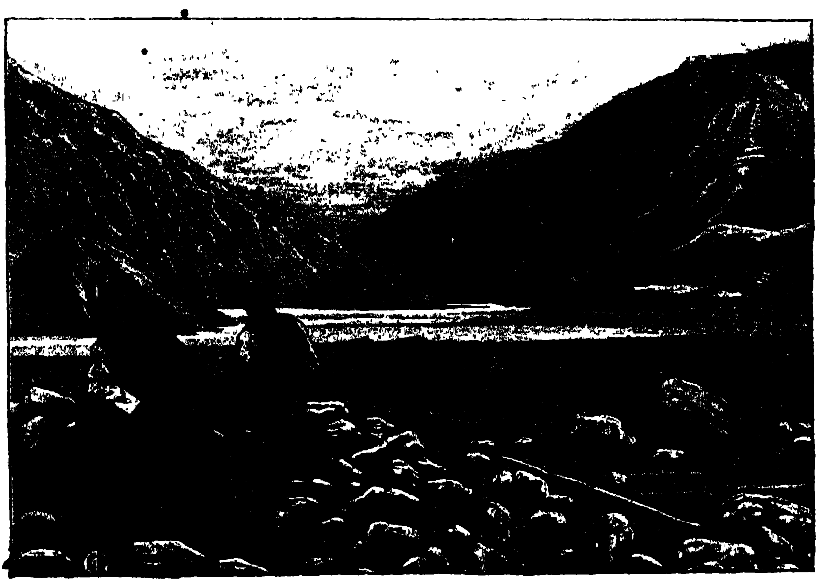

Fig. 11. Valley of the Sirkia river in Húndés; cretaceous rocks.

The system of beds which I have separated on the map and in my sections as cretaceous, form in all the sections hitherto examined by me a connected complex of strata, within which I could distinguish at least two horizons. These are in descending order:—

b.—White or light grey limestone, marly here and there, containing marine upper cretaceous fossils.	"Chikkim" limestone.	Upper cretaceous.
a.—The above rests conformably on a series of beds, amongst which a silicious grit or sandstone of brown to olive grey colour is the leading rock. Fossils I found very few and they were badly preserved.	"Gieumal" sandstone.	Lower cretaceous including perhaps Upper Tithon.

a. Sandstone series. Gieumal sandstone?

The series of sandstones and shales which are inclosed conformably between the Upper Spiti shales and the limestone (*b*), are well exposed in the sections between the Niti pass and the Sutlej in Húndés, and also in the watershed between the latter river and the Laptel drainage. The leading rock of the series is a grey quartz-sandstone, weathering brown, thin-bedded and alternating with silicious greenish-grey shales, which towards the upper portion of the series change into massive grey quartz-sandstone. Fossils seem rare in this rock. I have only a few badly preserved specimens of *Belemnites*, and I found these in a ferruginous layer close to the boundary with the Spiti shales.

From its stratigraphical position immediately above the Spiti shales, not less than from its similar lithological character, I am inclined to believe that the lower beds of this division may be identical with the Gieumal sandstone of Stoliczka. If so, the lowest horizon of this sandstone division must be looked upon as upper tithonian; since it has been ascertained that part of the black Spiti shales are of tithonian age (according to Nikitin), it can only follow that these sandstones are younger; and if so, I think it will be found that the upper beds, which form the greater mass of this division are neocomian.

b. Limestone series. "Chikkim" limestone.

The cretaceous sandstone series of Húndés I found overlaid by a light-grey, almost white limestone, which contains numerous fossils, mostly *Bivalves*, none of

which have yet been determined. My finds in this series are, however, very limited, as I could not devote sufficient time to fossil collecting whilst travelling in Tibet. It is identically the same rock as Stoliczka's Chikkim limestone, which occupies the same geological horizon. The limestone may be seen south-west of Dongpú in Húndés (Tibet), capping the (Gieumal) cretaceous sandstone of the Ma Rhi La, Balch Dhura, etc.; also south-east of Laptel.

Unconformity.

These form the last remaining patches of the cretaceous formation, which constitutes perhaps one of the most widely distributed of deposits amongst the sedimentary strata in Asia. Both fossils and lithological character of the two series point to great changes having occurred in the physical conditions under which these deposits were laid down. In the Himálayas and immediately adjoining areas there is no visible unconformity; such however may be observed in the areas further west, namely in Turkistán and Khorassán, where a decided overlap and unconformity exists between neocomian and the overlying upper cretaceous.

Distribution.

Stoliczka[1] was the first to notice cretaceous rocks in the Himálayas. It is now shown that this system is also represented in Húndés north of Milam and Niti; that it has a wide distribution in Tibet is demonstrated by cretaceous fossils which have been found in Eastern Tibet.[2] But this system is not only found along the whole length of the Himálayas, it extends also through Kashmir into Afghánistán, Persia and more or less all over Central Asia. I myself have wandered a good deal over the ground lying between our present North-Western Frontier of India and the Central Asian depression, and in numerous sections have met with a cretaceous series differing but slightly from that of the Central Himálayas. In the Sulaimán range a great thickness of sandstone rests on shales which I have already compared with the jurassic Spiti shales of the

[1] Mem., Vol. V, p. 116.
[2] Rec. Sur. Ind., X, pp. 21-26.

Himálayas. This sandstone, very silicious near the Takht-i-Sulaimán, is overlaid again by *Hippuritic* and *Coral* limestone of the cretaceous system. This sandstone is not only very similar in lithological character to the greenish-grey sandstone of Húndés, but it also corresponds with it in its stratigraphical position, and, I believe, will be found to represent the exact horizon of the Upper Gieumal sandstone.

All along the north-flank of the Hindú Kúsh, and further westwards, north of the Great Central Asian watershed, I found the upper jurassic alum shales overlaid by a sandstone, mostly reddish brown, often gritty and even conglomeratic. I traced this formation into Eastern Khorassán, and I believe it extends through Northern Persia into Armenia. The formation underlies the *Hippuritic* limestone, has yielded neocomian fossils, and occupies precisely the same stratigraphical position as does the sandstone (*a*) of Húndés.

The overlying light-coloured limestone with upper cretaceous fossils has a still greater distribution in Central Asia and the Perso-Áfghán area. It may be said to overlap the entire mesozoic formations and is therefore generally in marked unconformable position as regards the older rocks. Fragments of *Rudistes* in the Himálayan development of this limestone, and numerous remains of *Hippurites* in the cretaceous limestone of the Perso-Áfghán area enable us to say with considerable certainty that this horizon must be placed into the upper cretaceous system.

10. *Tertiary formations of Húndés.*

Lower and middle tertiaries.

The high plateau of Húndés is formed by a great synclinal of mesozoic and older rocks, which is filled to a large extent by deposits of tertiary age.

The latter form vast plains in which the Sutlej with its tributaries has eroded deep V-shaped valleys. Some of them are so deep as to have cut entirely through the horizontal upper tertiary deposits, and have thus exposed some strata which rest on the upper cretaceous

(Chikkim) limestone. Only in the sections in Húndés which lie between the Niti watershed and the Sutlej river did I myself see these strata, but there can be no doubt that they are of wide-spread extent north of the Himálayas, as similar rocks have been mentioned by Stoliczka and later observers as occurring far to the north-west in the valley of the Indus. Few exposures though there are of this nature, they yet are of great importance in the Himálayan sections. Perhaps the best exposure is afforded by the Sirkia stream; it cuts in succession through Spiti shales, the whole of the cretaceous system, and exposes rocks of a very peculiar nature lower down. Next, after the grey Chikkim limestone with fossils, follows a series of highly altered rocks, which at first sight might be taken to be members of a metamorphic series. Undoubted schists, altered limestones and phyllites they seem to be, associated with igneous rocks; there is a distinct dip of the series to the north-east, and as far as I could judge, it is conformable to the cretaceous beds further south. Only after a long search did I find sections of distorted *Nummulites* in a limestone about halfway through the series. Stoliczka's description of the Indus valley lower tertiary series tallies so completely with what I saw in Húndés, that I have no hesitation in saying that the latter beds must be part of an extensive *Nummulitic* formation, extending from the North-West Himálayas to the Manasarawar lakes, where similar eruptive rocks have played a great rôle (Strachey).

I noticed the same series (the limestone often of red colour) beyond the Balchdhura pass north of Milam.

Marching still further north-east, I came upon a pepper-and-salt coloured grey sandstone, very like some of the lower Siwalik sandstones, but probably unconformable to the altered *Nummulitic* formation with a high dip to north-east. In pl. 12. in the view of the Nukchung valley will be seen these lower tertiary beds dipping to north-east, and overlaid quite unconformably by the horizontally bedded younger tertiaries of Húndés.

In the absence of fossil evidence, all that can be said with tolerable certainty is—

(1) that there is a marine *Nummulitic* formation, apparently conformable to the underlying upper cretaceous, much disturbed and altered by masses of igneous rock, amongst which various gabbro rocks, and also a syenite is chiefly remarkable.

(2) Next in succession as far as can be seen is a sandstone, highly inclined, resting unconformably on the *Nummulitics*, and resembling some lower Siwalik beds, but which has not yielded any fossils.

(3) The whole is overlaid unconformably by the younger tertiaries of Húndés.

Younger tertiaries of Húndés.

The tertiaries of Húndés have excited considerable interest since the early days of Himálayan exploration. Perfectly horizontally stratified, they form a great thickness of beds, covering up all the older tertiaries and perhaps mesozoic rocks, which form the trough of Húndés between the Indian watershed and the Kailas range.

General Strachey[1] has already given a most graphic description of these deposits, and I can do no better than quote his remarks *in extenso*. "But the most striking feature of these mountains is probably that which I have next to mention, *viz.*, the existence of a great tertiary deposit at an elevation of from 14,000 to 16,000 feet above the sea, still preserving an almost perfectly horizontal surface. On crossing the watershed-ridge between the streams that flow to the south into the Ganges, and those that fall into the upper part of the Sutlej to the north, which here constitutes the boundary between the British territory and Tibet (see map), we find ourselves on a plain 120 miles in length, and varying from 15 to 60 miles in breadth, that stretches away in a north-westerly direction.[2] Its western portion is

[1] Quart Jour. Geol. Soc., VII, 1851.
[2] See pl. 12.

everywhere intersected by stupendous ravines, that of the Sutlej being nearly 3,000 feet deep. The sections afforded by these enable us to see that this plain is a deposit of boulders, gravel, clay, and mud, of all varieties of fineness, laid out in well-marked beds that run nearly parallel with the surface, and that hardly deviate from a horizontal position. The discovery of the fossilized remains of several of the larger *Mammalia* distinctly marks the tertiary age of this deposit. The existence of such fossil remains in the northern parts of these mountains had been long known, but we were altogether ignorant of the precise locality whence they came, and had no facts before us from which any conclusions could be formed as to their geological import. The Niti pass, from which it was said that the bones[1] had been brought, was not the place where they were found, but one of the routes only by which they came across the great Himálayan chain from unknown regions beyond.

So-called Niti fossils.

"Mr. Waterhouse, who has been so obliging as to examine the specimens that I procured from these beds, informs me that he recognizes amongst them the following:—Metacarpal bone and distal end of tibia of *Hippotherium;* patella of small horse; distal end of radius of a larger species of horse; distal half of tibia of a horse of very large size; part of metacarpal of a horse, upper end of tibia of bovine ruminant; dorsal vertebra of a ruminant. Portion of head of an undescribed animal allied to goat and sheep, having, like them, prominent orbits, and the horns above the orbits; but which differs in the peculiar form of the bony cone of the horns. The horns are remarkable for being placed very near to each other at the base (their upper portions are broken off). There is a specimen in the British Museum, however, from the same locality, of an animal very like this, in which the horns are seen to be short, stout, and slightly bent outwards at the apex. Right wing of the atlas vertebra of *Rhinoceros*; phalanx of one of the outer hind toes of ditto? and portion of tooth of *Elephant*? Specimens of the bones of *Rumi-*

[1] Called Bijli-ki-har (lightning bones) by the natives who ascribe medicinal and other virtues to these remains.

nants, *Pachydermata*, and other animals from this district, presented to the Society by Sir Thomas Colebrooke and Dr. Traill, are in the Museum of the Geological Society, London."

* * * * * *

Mr. Lydekker discussed the evidence offered by these finds of fossil bones and comes to the conclusion that the fauna ef the Húndés beds comprises "with the exception of the alleged occurrence of *Hippotherium*, which does not appear to me to rest on sure grounds, only living genera of mammals, all the extinct Siwalik genera being conspicuous by their absence, and I accordingly come to the conclusion from this and from the foregoing conditions, that the beds in question are probably of pleistocene. age, and almost certainly not older than upper pliocene."[1]

The former writers on this subject, amongst them Falconer and Strachey, assumed as probable that (1) these ossiferous beds were representatives of the Siwaliks, and (2), that as animals whose remains are found could not have lived in the high altitudes in which we find them now (about 14,000 to 15,000 feet sea level), the deposits must have been raised since Siwalik times to their present height. Lydekker has disposed of the first point, and has shown as most probable that these beds are younger than the Siwaliks.

As regards the second point, it is extremely unlikely from structural evidence that the ossiferous beds of Húndés have been raised to their present height after their deposition. I have shown that sandstone deposits younger than *Nummulitic*, and in lithological character closely resembling certain Siwalik sandstones, are unconformably overlaid by the younger tertiaries in Húndés. The sandstones here referred to are highly inclined, dipping north-east, and they cannot be older than miocene, and probably are even younger. When the horizontal deposits of Húndés were laid down, the Himálayas, including even deposits as recent as the sandstones in question, had passed through great changes, folding and compressing. I can offer no evidence at present to show that since the deposition of the ossiferous

[1] Rec. Geol. Surv. Ind. XIV, 181.

beds of Húndés any such changes have taken place, which could have lifted the high plateau of Tibet to its present sea-level, although evidences in neighbouring areas[1] point to the probability of the folding process being still continued to the present day. It is probable that the ossiferous deposits are lacustrine; both the confined situation which must have existed since middle tertiary times and the nature of the deposits seems to point to lacustrine origin as the only likely mode of its deposition. Also, in all parts of Central Asia hitherto examined, the change from marine to fresh-water conditions had set in in pliocene times, and the inference seems clear that also here the change of physical conditions had not been delayed into later tertiary times.

Assuming, therefore, a later pliocene and even pleistocene age for the ossiferous deposits of Húndés, as Lydekker has done with a good show of reason, it follows that no great change in physical conditions had taken place since that period; the structural relations of these deposits to the underlying beds preclude the theory of their having been disturbed on a large scale since the time of their formation.

PART II.

DESCRIPTION OF SECTIONS AND SUMMARY.

CHAPTER V.—PAINKANDA SECTIONS (GARHWÁL).

First season's work in the Niti area.

When I started work in the higher Himálayas in 1879, I began with the examination of the sections of the Painkanda district. The area which I visited at first, namely, the ground between Malari and Niti, remained almost unintelligible to me at the time. Fossils I found many, but few of them were characteristic ones, and the mass of debris which obscure all the lower slopes, together with the inaccessibility of most of the peaks above them, left me in great uncertainty about the true succession of

[1] See "Field notes," Rec. Geol. Surv. Ind., Vol. XIX, pp. 266, &c.; XX, p. 101.

the different formations of that ground until I reached the higher valleys north and north-east of Niti. Though a very highly elevated area, the ranges in that part of the Himálayas are singularly free from ice and snow, and the slopes being frequently easy of ascent, I obtained some very good sections, which remained for the rest of my work in the Himálayas keys to interpret more difficult ground. I may here remark that not only the succession of the groups, but also the general lithological character of the beds composing them, varies but very little throughout the extent of the Central Himálayas, from the frontiers of Nepál in the south-east to their north-western limits in the Spiti valley.* The only considerable difference discernible in the sections occurs in the upper carboniferous system, as will hereafter be shown. Later on, after I had finished the ground south-east of the Niti sections, as far as the Nepál Frontier, I found another opportunity of visiting the sections in the Painkanda area, and so was able not only to correct the results of my first season's work, but also to again compare work already done with the key sections of Niti.

Scale of section.

It may not be out of place to remark here that all the ideal sections given with this report, have been constructed on a natural scale, *i.e.*, the scale of the vertical and horizontal dimensions is the same, 1 mile = 1 inch. The recorded thickness of each individual bed and group has also been drawn to this scale as far as it was possible to do.

All the sections in this report are constructed from a base line assumed to be drawn at 10,000 feet above the sea-level, which is about the height of the lowest valley within the area of sedimentary rocks, and the heights given are generally those recorded on the large scale (1 mile = 1 inch) Survey of India maps, supplemented by heights determined by myself with a Newman's standard mercurial barometer.

Construction of sections.

To obtain an approximately correct outline for such ideal sections without the help of a map which shows true contour lines is always difficult, but I believe

that the outlines given in my sections will be found correct for all practical purposes. I adopted the following process for constructing the sections. On the assumed base-line of 10,000 feet above sea-level, I marked off all the horizontal distances of the chief points included in the line of section, and of all the points of which I knew the elevation. On co-ordinates drawn from these points I mark off the heights according to the same scale as the horizontal distances. By connecting the points so obtained, a rough outline of the section results, which only requires to be corrected for minor details, character of slopes, peaks, etc. The latter is easy enough in most cases. Most of the sections may be actually viewed in detached portions from adjoining heights, from which points I made camera lucida sketches, which serve to correct the character and outline of my ideal sections. So, for instance, the mass of the Chango may be seen from any of the heights on the left (east) side of the Dhauli valley, or from the Niti Pass.

Use of ideal sections.

There are some geologists who question the use of such sections. I believe the fallacy of such opinion needs scarcely any refutation; but I may remark that, in the first place in describing the geology of any area, I wish to put before the reader, not only the facts as I found them, but also must endeavour to give my own interpretation of them as graphically as I can. For this purpose I give not only natural profiles but also the sections, which will show my own intrepretation of the former. Without the aid of ideal sections I believe it is next to impossible to give a lucid description of a complicated mass of strata. Any one conversant with the construction of sections or diagrams will at once understand how far such sections are only to be understood to be diagrams, and how far they represent actual facts.

As regards the natural profiles I have only to remark that they have all been drawn with the aid of a camera lucida, and may therefore be absolutely relied on for accuracy of outline and proportions.

The lowest group in all the sections of the Painkanda area is formed by crystalline rocks, which build up the mighty chain of hills which extend from the Nanda Devi, Trisúl and Dúnagiri in a north-westerly direction, and end in the noble cone of the snow-covered Kámet. These crystalline rocks form as it were a wide arch or roof, with its apex greatly eroded and worn away, now mostly buried under masses of snow and ice. Huge glaciers fill the higher valleys in this range, and send down enormous masses of debris, often choking the narrow gorges of the main valleys into which they fall. One of the glaciers of this central range is the Raikana, the foot of which forms the beginning of section 1 of plate 1.

Crystalline rocks.

As already described in the chapter on the metamorphic series, it will be remembered that the upper beds of the crystalline series are schists. They are clearly of sedimentary origin, and pass upwards into the haimanta system; but I have separated them under the name of the vaikrita system. They are chiefly composed of mica-schists with talcose slates and thinly stratified gneiss. The latter shows the gradual passage from gneiss into mica-schist markedly, the gneiss stratum usually forming the centre bed of a group of schists, the outer strata of which are mica-schists passing gradually through quartz rock with garnets into a fine grained grey gneiss in which garnet forms one of the accessory minerals. The gneiss is often in thin flaggy beds, divided by a few inches of mica-schist, which is replaced here and there by talcose beds. An enormous thickness of metamorphic rocks is thus made up of a repetition of more or less similar series of schists and gneiss.

Schists. Vaikrita system.

Such is the vaikrita system which overlies the great mass of bedded gneiss which forms the main range of Garhwál and which is lithologically and structurally the same as Stoliczka's 'Central gneiss' of the north-western Himálayas.

Overlies the gneiss of the main range.

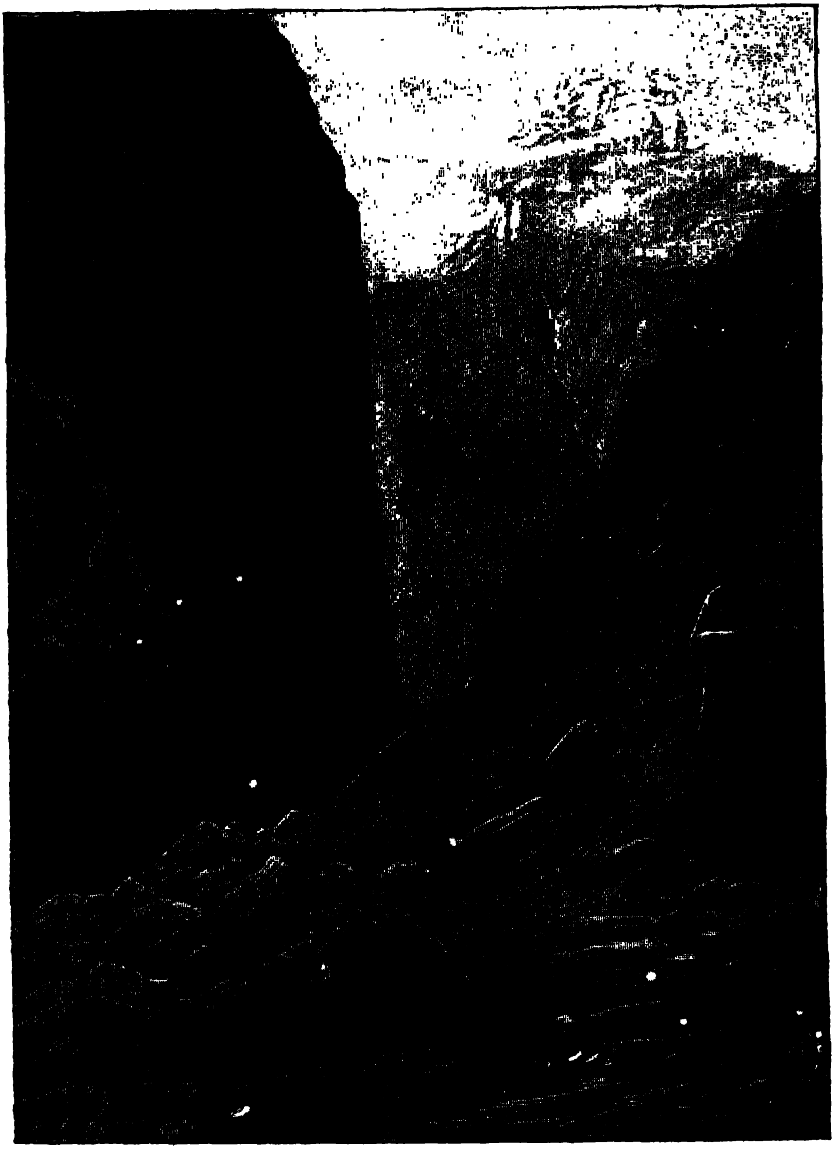

Fig. 12. Gorge of the Dhauli Ganga through the gneiss between Niti and Gamsali.

As already alluded to in the general chapter on the metamorphic area, and in a former paper[1] the great fold of the central mass of the Nanda Devi has its belt of younger stratified crystalline rocks on both flanks of the flexure, the top of the arch being denuded, as can be well observed in the Milam sections. In the Niti sections I could observe this belt only along the south-western flank of the main flexure; when entering the great gneissic gorge of the Dhauli Ganga between Joshimath and Niti the younger crystalline beds, the vaikritas, seem to dip below the gneiss of the southern range of the Central Himálayas. The great fold which forms this range is formed (as indeed all along the line of the Central Himálayas) of an unsymmetrical and inverted flexure the shorter limb being the southern one, dipping to north-east; hence the apparent underlie of the younger crystallines below the gneiss (see fig. 1, Records XIII, p. 84).

Unconformity between gneiss of main range and lowest palæozoics.

The section north-east of the main axis between Malari and Niti shows the lower palæozoic group as resting immediately on porphyritic gneiss of the southern range of the Central Himálayas which is shown in the sections of plate 3. The contact between the gneiss and the semi-altered beds of the lower palæozoic seems perfectly natural. But it is extremely probable that the vaikritas have been cut out in these sections by a reversed fold-fault along the longer limb of the great central flexure of the main range. The younger crystallines, the vaikritas, pass into the overlying haimantas in all the other areas of the Central Himálayas, and form also a part almost of the great porphyritic gneiss (central gneiss of Stoliczka) elsewhere, that the inference seems natural that the vaikritas are only wanting in the Niti sections because they happen to be cut out by a fold-fault of considerable length.

[1] Records Vol. XIII, p. 83.

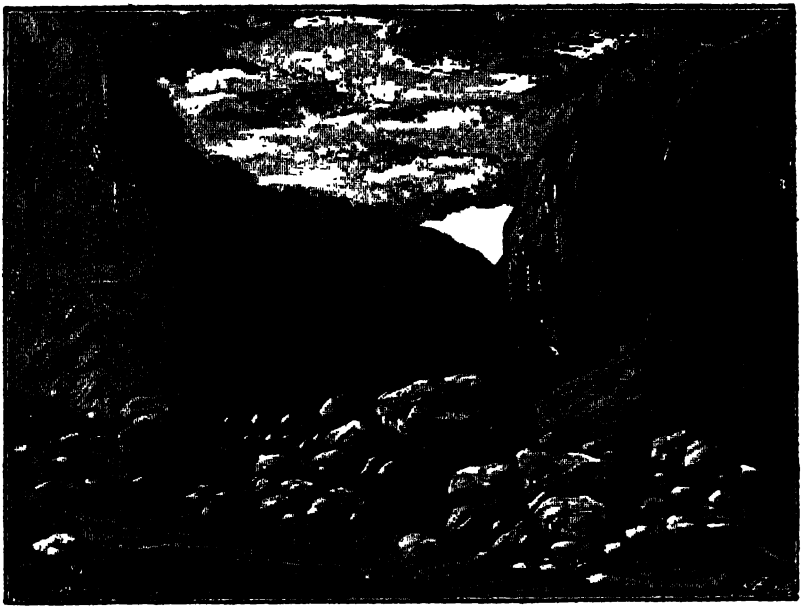

Fig. 13. Gneiss gorge at Bampa camping ground.

Gneiss of Raikana heights.

The Raikana heights (section 1, pl. 3) are composed of thick beds of coarsely crystalline, almost porphyritic gneiss throughout which large felspar twins are scattered generally along planes of stratification, round which the other minerals of the rock group themselves, in fact forming an 'Augen-Gneiss.' Amongst the accessory minerals garnet is the most conspicuous; tourmaline and blue kyanite crystals are also frequently met with. This gneiss in irregular thick beds composes the north-eastern slope of the Raikana heights, dipping from 30 to 40° below the palæozoic group.

Albite granite.

The gneiss of the Painkanda sections is traversed in all directions by veins of albite granite, which show distinctly in the darker gneiss of the Raikana peaks. A fine view of the latter with its net-work of granite veins may be obtained from the Bamlas (16,681′) on the left side of the Dhauli Ganga.

Chango peaks.

North-east of the Raikana heights and partly separated from the latter by the gorge of the Raikana river, rises the grand mass of the Chango, 20,216 feet above the sea, of bold outline, and snow covered. The south-western slopes are obscured by enormous masses of glacial debris, whilst the south-eastern flank of this mountain mass is nearly everywhere inaccessible. There it forms a narrow, highly picturesque gorge, which the river Dhauli has scooped out of the older palæozoics. The Raikana river, which drains the enormous glacier filled valleys of the Kamet peak, runs as nearly as possible along the line of contact between the gneiss and the lowest palæozoic group. The two rivers, the Raikana and the Dhauli Ganga, converge and lastly join about 1½ miles north of Goting[1] from the projecting spur of the Kharbasiya (18,806′) which admirably discloses the structure of the lowest palæozoic rocks, which is well shown in the precipitous slopes of the Kharbasiya and Chango. The gorge of Kharbasiya formed by the Dhauli Ganga, exposes the slates of the haimanta system (azoic of Strachey), most intricately crumpled and folded. Not only are the beds of it crushed and folded, but also jointed and traversed by innumerable faults, each one of which has displaced its block of strata at least a few inches, but the sum total of these displacements must be enormous. The total thickness would therefore at first sight seem to be very much greater than it really is; I think it can scarcely exceed 3,500 feet, if so much, this estimate having been arrived at after studying a great many sections through the haimantas. A good section showing the thickness of the system is that north of Goting, where it may be measured barometrically. There the haimanta system is sharply defined and a good section is exposed. It consists of—

Lower palæozoic rocks of Chango and Kharbasiya peaks.

Structure and thickness of the haimantas.

Red quartzitic shales. Greenish shales.	Numbers in the figured sections. 3.
Purple quartzite and conglomerate.	2.

[1] Niti is the last village on this route to Tibet. When places are mentioned beyond this (or in Húndés) camping grounds are meant.

This system of strata, which is identical with General Strachey's azoic group rests directly on the gneiss of the Raikana heights, and is overlaid by fossiliferous lower silurian beds, the division 4 in the sections. There is absolute conformity between the lower divisions 2 and 3 and the lower silurian beds; in fact the passage is gradual from the densely red quartz shales, (3) into the *Coral* limestone, (4) of the lower silurians. The red quartz shales (3) are never absent in any of the sections of the Central Himálayas which I have examined, and they form one of the most constant and easily recognized features in the Himálayan sections. With them, underlying them, occur some greenish silicious shales, resembling phyllites and in a bed of such, in section 1 of pl. 3, on the slope overhanging the Kharbasiya encamping ground I found some indistinct fossil remains of *Bellerophon*? and bivalves. They were the only fossil traces which I found in beds below the silurians.

Overlaid by lower silurians.

Fossils.

This band of red and greenish quartz shales may be seen to wind all round the steep cliffs of the Kharbasiya point, and the lower slopes of the Chango. Conforming to the contour of the hills, it finally runs down into the deep valley of the Dhauli Ganga, re-ascends the slopes on the left side of the valley and can be seen in the far distance above the rugged contour of the hills, sharply defined as a red line dividing the purplish rocks underneath, from the dark silurians above.

The great fault shown in the sections 1 to 3, pl. 3, and in the profile, pl. 6[1]) has cut off a part of the pre-silurian haimanta system and the red shales (3) may again be seen beyond the Ganes Ganga underlying the silurians.

[1] The numbers in this plate do not correspond with those in the sections. In pl. 5. they represent the following: 1. Haimanta slates, conglomerates, etc. 2. Red quartz shales. 3. Lower Silurians. 4. Upper Silurians. 5. Dark *Coral* limestone (devonian). 6 Red *Crinoid* limestone (Carboniferous). 7. White quartzite. 8. Dark *Productus* shales. 9. Lower trias. 10. Muschelkalk. 11. Daonella limestone. 12. Upper limestone. 13. Brown limestone (upper trias). 14. Rhaetic dolomite. 15. Rhaetic *Lithodendron* limestone.

The lowest member of the haimantas is well represented in the lower part of the Kharbasiya gorge. Here the river has eroded through the thick beds of hard dark purple quartzites and conglomerates, forming steep precipices on each side. The lower portion of the formation rests immediately on the gneiss and consists of massive, but irregular beds of the quartz conglomerate which I found in all the sections where the haimantas are exposed in the Himálayas. As their character does not in the least vary over the entire extent of area, I refer to the paragraph, p. 51, for its description. This conglomerate, which in places strongly resembles a boulder-bed, merges into massive intensely hard dark purple quartzites; but even in the latter I found occasional strings of quartzite or gneiss pebbles. Conglomerate layers occur again at several horizons, identically the same as in the bottom beds. That they are separate horizons, not repetitions through faulting or folding, is clearly seen in the grand cliffs formed by the Kharbasiya gorge. The quartzites and conglomerates merge upwards into the red quartz shales (3).

Lower haimantas of the Kharbasiya gorge.

A broad belt of the division (2) may be seen along the slopes on the left side of the Dhauli Ganga, and again on both sides of the Ganes Ganga, where the fault shown in the sections on pl. 3 has pushed the haimantas over younger strata.

Left side of the Dhauli Ganga; Ganes Ganga.

Each one of the streams which join the Dhauli Ganga on its left side has exposed good sections of the haimantas. The road from Niti to Húndés passes partly along the boundary between the division 2 and the gneiss, and the road from Niti to the Marchauk pass crosses a wide belt of the entire system, both 2 and 3.

The dip of these strata varies considerably, but averages about 30° north-east in the sections north-east and north of Niti.

The Shanti stream near Niti, which drains the heights over which the Chor Hoti pass leads, exposes along a distance of about 4 miles fine sections of the haimanta system, greatly contorted and crushed. Faulting to a large

Shanti valley.

extent has shattered the haimantas and its adjoining formations so much that a correct mapping of the various boundary lines would be an impossible undertaking on the small scale of an inch to the mile even; several blocks of the underlying gneiss are brought up again and again during the 4 miles between the small glacier on the south-side of the Chor Hoti and the junction of the Shanti stream with the Dhauli Ganga. The annexed figure 14 will give an idea of the compli-

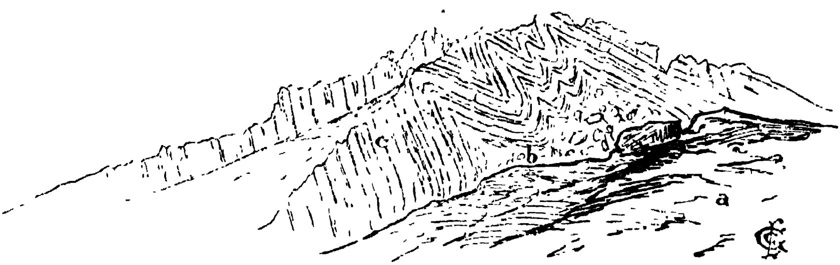

Fig. 14. Folding of the haimantas in the valley of the Shanti stream. *a*. Gneiss; *b*. Conglomerate; *c*. Shales of the haimantas.

cated character of the faulting in the region. The sketch was made in the valley of the Girthi river, immediately south-east of the Kurkuti Dhár which forms the left side of the Shanti valley.

The faults and disturbances seen in the latter locality are of course visible in the Girthi valley also, where they are intensified by the nearness to the great Girthi river fault shown in the map, close to which immense crushing has taken place.

Fold-fault.

The existence of the fold-fault near the boundary between the haimantas and the gneiss can only be conjectured (see page 92), for in the sections of the Shanti and Girthi the contact seems conformable and natural, as for instance in the cliffs east of Gamsali, where both the gneiss and the overlying purple quartz conglomerate and slates dip about 35° east. The crushing and faulting which the whole palæozoic group suffered in these sections has brought about many positions, which alone seen would puzzle one considerably. So for instance in the Girthi valley near Kotim camping ground the division 2 is crushed in steep folds

against the underlying gneiss. As Kusai camping ground in the Shanti valley silurian limestone on the left side of the valley seems to dip below the purple quartzite (2) on the right bank of the stream, the latter being pushed over the former. Near Kolajábar camping ground at the foot of the Chor Hoti pass, we see red and green haimanta slates, the latter with traces of *Bellerophon sp.* dipping below lower silurians. The red slates show as a distinct band all along the very rugged cliffs which form the steep sides of the Shanti valley, capped by the dark coloured silurians.

Near Malari I observed that the coarse quartz conglomerate (2) rests directly on the gneiss which forms the great hill masses south-west of that village. The Dhauli Ganga runs through a narrow gorge eroded through the gneiss beds, and the contact between them and the overlying haimanta conglomerates is plainly seen and appears to be perfectly natural. A minor fault, which I have not traced further south-eastwards, cuts off a portion of the haimantas over which a small mass of gneiss is pushed from the north-east, thus producing a repetition of the section.

At Malari.

Immediately north-east of the village of Malari I noticed that albite granite penetrates the gneiss and enters the conglomerate. This is the only instance of granite intruded into haimantas which I have observed in the Niti or Milam areas. Further eastwards the feature is common enough.

Granite in the conglomerate.

Due east of Malarí, about a mile and a half from it, rises the Painkanda peak (19,340 feet). The western slope of it exposes good sections of the entire palæozoic group. Ascending the mountain mass by the rocky spurs, which connect the highest points with the slope just above Malari, I found the purple conglomerates with the bright purple and dark coloured quartzites which form the haimanta system strongly developed and steadily dipping north-east below the band of quite unfossiliferous bright red or pink quartz shales. They are seen to run along the entire western slope of the hills, conforming to the general contour of them, and may be traced by their distinctive colour miles away to the south-east. The silurian and carboniferous

systems follow in regular succession to the top of the Painkanda peak itself, which is formed of the sugar-grained, white quartzite (8) of the upper carboniferous.

Profile from Malla Shilanch east of Malari.

Standing on the heights east of the Painkanda peak, which overhang the valley, the upper portion of which is filled by the Uja Tirche glacier, an ice stream some 7 miles long, one may observe the structure of the lower

Fig 15. Palæozoic group of the Kurkuti heights from Malla Shilanch grazing grounds

palæozoic groups, which form the stupendous and almost inaccessible heights on the left side of the Girthi river (see fig. 15). Here again the red quartz shales (3) which closes the haimanta system upwards serves to mark out the boundaries. It divides the dark purple rocks at the base from the dark greenish blue strata of the silurian. A band of the densely red shales runs like a red thread along the entire south-west slope of the peaks, at the base of which the grazing grounds of Lam Shíruáns are situated.

Again, nearer the foot of the Uja Tirche glacier the red shales of

Red shales (3) near Lampak.

the upper haimantas help to clear up what otherwise would be a scarcely intelligible jumble of dark coloured beds. On the slopes of Lampak grazing grounds, vast masses of glacier debris have obscured the rocks below; and where the latter peep through the accumulations of disintegrated fragments, they are seen to be composed of greatly contorted strata, mostly of silurian age and yielding fossils belonging to that system. The steep cliffs which form the right side of the glacier valley are seen to be formed of strata raised up on end and greatly contorted.

Badly preserved fossils are seen here and there in these dark, mostly calcareous beds, but the great altitude, together with the impossibility of paying more than a flying visit to this desolate region, would make closer study exceedingly difficult, were it not again for the red thread which runs through it all, namely, the densely red coloured quartz shales (3) which overlie the purple conglomerates and quartzites (2) of the haimantas and divides the latter from the dark bluish green limestones and shales with fossil traces, belonging to the lower silurian *Coral* limestone division.

The quartzites (2) of the haimantas rise in gigantic cliffs to over 20,000 feet and form the western spurs of the Nanda Devi peaks; the beds dip north-east by north, some 50 to 70°, and the boundary between them and the overlying silurians are seen near the foot of the glacier.

In all the sections of the Painkanda district I found that the al-

Silurians of the Painkanda sections.

ways uniform red quartz shales (3), which terminate the haimanta system pass gradually, though most distinctly, into silicious shales of a light green colour, apparently devoid of fossils, amongst which calcareous beds are intercalated higher up; the latter contain traces of fossils. Some fifty feet higher up the limestone beds predominate, and the series becomes simply a succession of limestone strata, amongst which *Coral* limestone predominates. This division is marked 4 in the sections.

The silurian series is nowhere else better seen than along the

Along the lower slopes of the Silakank.

lower slopes of the Silakank peaks No. 2, the highest point of which is 19,265, and which descend, in more or less unbroken lines, down to the Dhauli Ganga. Near the gorge of that river, between the junction of the latter with the Silakank ravine and with the Ganes Ganga, the Silakank slopes possess no undercliff of debris, but bare precipices of haimanta shales are seen to descend direct down to the base of the gorge. Pl. 6 gives the view facing the Silakank stream descending from it. Near the left of the river will be seen the rugged, but steep slopes, falling down towards the Dhauli Ganga gorge, composed of the jointed masses of the greenish shales of the haimantas[1] (1) with the bright red quartz shales (2) clearly marking a boundary against the sombre coloured, dark *Coral* limestone of the lower silurians.

Fault.

The opposite side of the Silakank stream in the same profile exposes the great fault (see map), which has brought the upper carboniferous into direct contact with the whole group of palæozoic beds below, the latter having been pushed over the former. This fault divides the Upper Painkanda area into two separate successions of the same group of formations. South of the fault, I observed that the silurian system (in company and closely connected structurally with the haimantas), forms the basement, as it were, of the sedimentary cap which rests on the high masses of the Chango, Daldakharak, the Damján and Marchauk peaks, and the Hóti and Kurkuti heights, and further south and south-eastwards also of the Painkanda and Magram masses. The same may be observed in the neighbouring, snow-covered, and almost inaccessible regions of Johár. The silurian fossiliferous beds form only narrow bands as it were at the base of the palæozoic rocks, and excepting close to the great line of fault or faults, conform more or less to the contour of the hills, which they intersect at an angle of about 25° to 30°.

North of the fault there is only one area of silurian rocks in Painkanda Mallas, namely, a narrow strip which overlies the haimantas

[1] By mistake the various divisions were numbered differently in this plate.

on the left side of the Dhauli near Patálpáni and forms also the left side of the Ganes river, from near the camping ground on that river on the road to the Niti pass to the main range near the Gwáldankar camping ground.

Section of the Pethathali ravine.

The section of the lower Silakank slopes near Pethathali camping ground is almost undisturbed, if we except jointing and local crushing and the beds of the lower palæozoics dip steadily to the north-east at an angle varying from 30 to 40°. I found in descending order the following beds:

UPPER SILURIAN.

	Thickness feet.
Towards the top very hard dirty pinkish grey and dark quartzite, alternating with greyish green, micaceous shales, phyllitic. The quartzite beds are often replaced by dark *Coral*-limestone. The greenish shales show *fucoid* markings and all the beds yield numerous fossils, which are best preserved in the *Coral* limestone. *Orthis sp.*	...
Lower down the shale beds decrease in frequency, and the pink or rather dirty flesh-coloured quartzite predominates and its beds are thicker	710
Flesh-coloured quartzites, alternating with shales and *Coral* limestone. The shales with *fucoid* markings are more frequent near the top, whereas lower down the limestone beds divide the quartzite and they yield many fossils, *Corals*, *Orthis*, etc. . .	22
About 10′ of *Coral* limestone followed by flaggy beds of flesh-coloured quartzite divided by calcareous *Coral* beds . . .	40
Massive beds of *Coral* limestone, alternating with thick beds of flesh-coloured quartzite, which latter are associated with thin partings of green shaly beds	38
Quartzite beds alternating with greenish grey silicious shales, which latter show cleavage. *Fucoid* marks are chiefly found on the shales, whereas in the quartzite *Corals*, *Encrinites* and *Brachiopods* abound. The shales increase in thickness higher up . .	280
Shales, divided by a thin bed of quartzite	2
Flaggy bed of quartzite	1
Grey, very friable shales with thin partings of quartzite	6
Quartzite in thick flaggy beds, alternating with very friable, grey shales with *fucoid* markings. *Corals*, *Encrinites* and *Brachiopods* in the quartzite	35
TOTAL .	1,134

LOWER SILURIAN.

	Thickness, feet.	inches.
Dark coloured *Coral* limestone	19	0
Quartzite	3	0
Silicious shales	2	6
Limestone with shaly beds	9	0
Limestone	30	0
Silicious shales	1	6
Very hard dark-coloured *Encrinitic* limestone with *Corals*	42	0
Quartzite (no fossils)	22	0
Dark limestone	1	8
Quartzite with shaly partings	8	0
Silicious shales	1	5
Concretionary limestone with quartzite beds and flaggy limestone partings	9	0
Dark limestone with shaly silicious beds and dark blue concretionary limestone	21	0
Grey quartzite and limestone, weathering brown	1	6
Flaggy beds of *Encrinite* limestone with fossils	15	4
Dark limestone beds with thin partings of quartzite showing cleavage and traces of *Encrinites*	3	0
Flaggy whitish quartzite, weathering brown	4	0
Flaggy quartzite with beds of fossiliferous limestone	4	0
Greyish, drab-coloured quartzite	0	6
Grey shaly quartzite with limestone partings	0	8
Quartzite and limestone in thin alternating beds	0	9
Thin beds of quartzite with fossiliferous band of shaly limestone	1	5
Greyish, dirty flesh-coloured quartzite with shaly partings	3	0
TOTAL	204	3

Underlying : red quartz shales (3).

The thickness of the divisions of the silurian system of the Silakank are therefore—

	Feet.
Upper Silurian	1,134
Lower ,,	204
Total thickness of the silurian	1,338

Continuity of palæozoic group

Not only in this section, but in every one which I have examined in the Himálayas, the palæozoic forms a perfect and continuous sequence of beds from the phyllites and quartz shales of the haimantas, to the uppermost beds of the carboniferous system, varying, it is true, in lithological characters, but always with gradual passages between the different rock formations and without the slighest unconformity. Therefore the divisions which I have distinguished in the Pethathali section must not be understood to form sharp and well-defined formations, but

rather as a series of beds having similar lithological character and distinct fossil remains.

Divisions of silurians in the Silakank section.

The silurian system may therefore be said to consist of the following principal divisions:—

	Number in the figured sections	
Upper silurian about 1,100 feet thickness.	5	Alternation of dirty pink and flesh-coloured quartzite with dark-blue limestone. Alternation of flesh-coloured quartzite with greenish grey shales.
Lower silurian about 200 feet thickness.	4	*Coral* limestone with greenish shales and quartzite. Concretionary dark limestones with *Corals* and flesh-coloured quartzite.

As will be seen, the prevailing rock of the silurian system in this section is a flesh-coloured to brown quartzite with fossils; this type of beds is best developed in the centre part of the system, and with it is associated near the base, *Coral* limestone, towards the middle of the section greyish and green shales, and towards the top, concretionary dark-blue limestone. The passage from the highest beds of the silurian system, into the overlying devonian or lower carboniferous *Coral* limestone, is gradual and single beds of flesh-coloured quartzite are found high up the series of limestone and shales which, I believe, belong to the carboniferous system.

The above section is almost the only instance I have met with during several years' work in the higher Himálayas, which permitted an easy and nearly accurate measurement of the thickness of its several beds to be taken. At other localities I found the lower palæozoic formations either greatly folded and crushed, or partially hidden by masses of glacier ice and snow, and preventing thus even an approximately accurate estimate of their total thickness. But I consider the Pethathali section a fairly representative one, and I may here mention that I have found almost identically the same beds at localities widelv separated, such as, for instance, Spiti and Dharma. The silurian rocks form the lowest part of the steep cliffs on both

Silurians on the ascent to Niti pass.

sides of the Pethathali and Silakank streams, the gorge of the Ganes Ganga between the ascent to the Niti Pass (see fig. 16) and the junction with the Silakank stream is also composed of rocks belonging to the silurians. The beaten track which leads to the Niti Pass within this gorge travels over fans composed of debris of silurian rocks. Near the halting ground Ganes Ganga, the middle silurian quartzites are well exposed and yielded some few fossils chiefly *Orthis*.

Fig. 16. Profile of the Niti pass.

1. Haimantas.
2. Upper silurian.
3. *Coral* limestone.
4. Red *Crinoid* limestone.
5. White quartzite.
6. Trias and Rhætic.

The belt of silurians may be traced on the left side of the Ganes Ganga valley to the western slopes of the high Niti peaks, where they are seen to strike below the younger rocks of Húndés, skirting the north side of the Kamet and Mána heights, and re-appearing in the Mána Gádh near Nilang. Forming, however, as they do the lower part of the cliffs south-west of the Niti peaks, they are to a large extent hidden by huge masses of debris, chiefly of fragments accumulated in enormous cones which skirt the hill sides. No sort of detailed examination of the system could profitably be undertaken there, and beyond finding isolated outcrops of rocks belonging to the silurians I had to content myself with settling the fact that the sequence of beds is the same as a few miles south-east near Pethathali, and that the system is conformably overlaid by the carboniferous rocks.

Extent of silurians near the Niti peaks.

South of the great fault (see plate 6 and sections on pl. 3) the silurians are seen to dip at an angle of about 30° below the overlying carboniferous rock, and form a belt of almost uniform width near the upper part of the slopes of the Marchauk and Hóti peaks. Here the sequence of beds is essentially the same as that which I found in the Pethathali ravine. Standing on any of the Dámjan heights or viewing the enormous mountain masses of the Marchauk from the heights near Góting, the silurian belt is very conspicuous even at a great distance. The densely red shales near the base of the silurian *Coral* limestone, the latter a very dark-coloured narrow band, and the dirty flesh-coloured broad band of the middle and upper silurian beds, may easily be traced along the upper slopes of the Dámjan heights where they conform more or less to the contour of the hills.

South of the fault.

The exploration of the Central Himálayas is connected with such great physical difficulties for the explorer that it is hardly ever possible to revisit places of geological interest, and thus it happened that I could only once inspect the section exposed by the Hóti pass, although I visited the Niti valley and pass twice. I would therefore recommend any future

Chor Hoti Pass.

student of Himálayan geology to visit the Hóti sections, as most likely to yield good exposures. Even there the silurian system (and with it the overlying younger palæozoics) has suffered so much by contortion and crushing that it is impossible to arrive at any reasonable estimate of its thickness.

A dense fog, with snow and rain, came on as I attempted to cross the Chór Hóti, which prevented my further work there; but I found the southern slope of this gigantic mountain mass to consist of the silurian system as seen south-west of the Silakank peak No. 2 (Pethathali stream), and I have been able to collect some fossils, mostly in the lower division, about 1½ miles above the Kolajabar camping ground, where the red quartz shales (3) are overlaid by the following section. In descending order:—

6. Beds of hard dark-blue *Coral*-limestone with *Spirifer sp*, *Orthis* sp. etc.
5. Shaly silicious beds.
4. Thick-bedded reddish limestone
3. Reddish purple *Coral*-limestone
2. Gritty limestone with fossil traces
1. Thick-bedded dark-blue *Coral*-limestone.

Higher up in the section follows the silicious series of the upper silurians, whilst the uppermost part of the range over which the Chór Hoti pass leads, is composed of the white quartzite (8) with reddish brown *Crinoid* limestone (7) which certainly belongs to the carboniferous system, and which overlays the blue limestone (6) which is probably devonian (see section 3, pl. 3).

The further extension of this section towards the north-east by east I reached from the Marchauk pass (north), and came thus again on to silurian rocks cropping up beneath the younger palæozoics of the Chor Hoti heights. The silurian rocks there form the steep rugged slopes of Rimkin and the Kurguthidhar heights, but they are to a great extent covered up by an immense talus and moraine matter. South-east of Rimkin, the silurian system is faulted against the triassic system, and some excellent examples of crumpling near the line of fault is shown in the cliffs

North-east of the Marchauk.

south-west of Rimkin. A number of small glaciers descend from the Hoti and Kurguthidhar heights into the valley below, nearly filling the deep ravines, which expose good sections of the silurian system, (see fig 20).

From Niti to the Marchauk pass.

The sheep track which leads from Niti to the Marchauk Pass winds up the Bamlas heights, where the natural contact between the haimantas and the metamorphic series may be observed. As far as Dámjan encamping ground the track moves more or less along the boundary of the haimanta system (the red quartz shales (3)) and the silurians. But from Dámjan camping ground the path leads almost at right angles over the silurian belt to the Marchauk pass, and so affords some good exposures (sect. 2 in pl. 3). Unfortunately the palæozoic group is so much crushed along the entire section and local faulting brought about not only several repetitions of the various divisions, but there may be observed total inversions, so that without applying the key of the Pethathali section to it, it would be next to impossible to unravel the structure. As it is, I can only show the complicated structure of these heights diagramatically in my sect. 2 on pl. 3, but on the map, I found it altogether impossible even approximately to indicate these inversions and minor faults, and had to content myself to show a continuous belt of silurian rocks roughly divided into three divisions.

Painkanda heights.

East of Kurkuti, in the Girthi valley, a fault has pushed the haimanta rocks (with overlying silurians), over the silurian system of the Painkanda peak (19,340'). The Kurkuti heights with the silurian cap is seen from the Painkanda south of it.

The Painkanda, itself, is a great triangular cone, formed of silurians, capped by a remnant of carboniferous rocks, the whole resting on the purple coloured quartzites (2) and red shales (3) of the haimanta system, which are well exposed on its western slopes, descending down to Malari. Fossils are scarce in this locality, and seem generally badly preserved. But the rocks are easily recognized,

the more so, as the red haimanta shales (3) exactly define the base of the silurians.

The belt of silurians (with its base of red quartz shales (3), sweeps in a curve round the enormous peaks (21,341′, 23,220′, &c.) which form the northern buttresses of the still higher Dunagiri (23,184′), and are well exposed in the snowy regions of the Uja Tirche glacier. On the left side of this glacier may be seen the crushed lower beds of the silurians, on the weathered surfaces of which fossil traces may be observed in abundance, though few well-preserved specimens can be extracted from the rock. On the right side of the glacier the middle and upper quartzites of the silurians (with many fossil traces) are seen in situ, much crushed and contorted, but clearly overlaid by the carboniferous rocks of the heights (20,344′, &c.) which form the left side of the Girthi valley (see pls. 2 and 10).

There is no marked boundary between any of the members of the palæozoic group; on the contrary the passage from one into the other of the systems is often very gradual. In the Niti sections I observed that the beds above the red quartz shales (3) and the strata below the red *Crinoid* limestone (7) form a perfect stratigraphical group, within which the passages between the various divisions are so gradual that it is exceedingly difficult to draw definite boundaries, although the average lithological types of the various divisions are distinct enough.

The devonian (?) and carboniferous systems in the Niti sections.

It is, again, the section exposed along the Pethathali ravine south-west of Silakank No. 2 (19,265′) which offers the most favourable conditions to study the carboniferous system, and which afforded an opportunity of taking measurements, which elsewhere I found to be almost impossible.

The uppermost silurians in the Silakank section I found conformably overlaid by a complex of beds, the leading character of which is that of a dark-coloured, somewhat splintery and concretionary

Lowest carboniferous (devonian ?) (6). Silakank section.

south-west of Rimkin. A number of small glaciers descend from the Hoti and Kurguthidhar heights into the valley below, nearly filling the deep ravines, which expose good sections of the silurian system, (see fig 20).

From Niti to the Marchauk pass.

The sheep track which leads from Niti to the Marchauk Pass winds up the Bamlas heights, where the natural contact between the haimantas and the metamorphic series may be observed. As far as Dámjan encamping ground the track moves more or less along the boundary of the haimanta system (the red quartz shales (3)) and the silurians. But from Dámjan camping ground the path leads almost at right angles over the silurian belt to the Marchauk pass, and so affords some good exposures (sect. 2 in pl. 3). Unfortunately the palæozoic group is so much crushed along the entire section and local faulting brought about not only several repetitions of the various divisions, but there may be observed total inversions, so that without applying the key of the Pethathali section to it, it would be next to impossible to unravel the structure. As it is, I can only show the complicated structure of these heights diagramatically in my sect. 2 on pl. 3, but on the map, I found it altogether impossible even approximately to indicate these inversions and minor faults, and had to content myself to show a continuous belt of silurian rocks roughly divided into three divisions.

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It is, again, the section exposed along the Pethathali ravine south-west of Silakank No. 2 (19,265′) which offers the most favourable conditions to study the carboniferous system, and which afforded an opportunity of taking measurements, which elsewhere I found to be almost impossible.

Lowest carboniferous (devonian ?) (6). Silakank section.

The uppermost silurians in the Silakank section I found conformably overlaid by a complex of beds, the leading character of which is that of a dark-coloured, somewhat splintery and concretionary

limestone. This system of beds marked (6) throughout my sections is in descending order as follows :—

	Thickness. feet.
Dark-blue hard limestone with *Crinoids*, *Corals* and *Orthoceras sp.*	36
Bluish-grey earthy shales (showing cleavage) with partings and thin beds (2") of limestone at exact intervals of 1'6", dip 33° N.E.	60
Massive dark-grey limestone with *Encrinite* stems; towards the base the limestone becomes very concretionary in layers of 1' 3" thickness, alternating with flaggy beds, which are divided by thin shaly layers	120
Thicker beds same as 4, with thin partings of shales . . .	100
Massive dark-coloured splintery limestone, very hard and without partings of shales ; traces of *Corals* and *Encrinites* . . .	220
Hard dark-coloured limestone with some shaly partings ; towards base some flaggy beds of flesh-coloured quartzite, and near the boundary with the underlying upper silurians, passing gradually into the same	130
TOTAL	666

Rests on upper silurians (5).

The system (6), the prevailing rock of which is a dark limestone, rests on the flesh-coloured quartzites, &c., (5) of the upper silurians, and is overlaid by the red *Crinoid* limestone (7) in all my sections. As I have already explained in the chapter on the carboniferous system, this complex of limestone may possibly be looked upon as an equivalent of the devonians ; in support of this I have nothing to offer, but the evidence of *Coral* remains, which occur both in the devonian and carboniferous systems, and the stratigraphical position immediately above and close lithological connection with the silurians.

Thickness increases further south-east.

In the Niti sections it may be seen invariably above the flesh-coloured quartzites (5), and I believe that it swells out to far greater thickness further to the south-east, towards the Milam area, although I have not been able to obtain measurements there. From the high ground south-west and south of the Niti pass, the dark, steep cliffs of this *Coral*-limestone (6) can be traced along the left side of the Dhauli river, where it forms the high projecting spur (15,900') south-west of the Silakank No. 2,

and the greater part of the lower slopes on the right side of the Silakank stream.

The Chango.

The snow-covered, ice-skirted peaks of the Chango (20,216′) are also formed partly of the dark limestones of this system (see sect. 1, pl. 3). At the latter locality I touched the devonians in only one place, namely, at the upper part of the Daldakharak No. 1 glacier, which has scooped out its trough in the carboniferous system. The angular debris with which the surface of the glacier is covered and which spread in an enormous fan several thousand feet to the valley below are entirely composed of fragments derived from the upper carboniferous quartzite (8), the red *Crinoid* limestone (7) and the dark blue *Coral*-limestone (6). The higher slopes of the Chango are practically inaccessible, excepting here and there, but fortunately the colours of the several divisions are so distinctive, that I was able easily to trace the approximate boundary of the beds along the eastern slopes of the Chango, as seen from the opposite heights.

South-west of the Silakank.

The range which extends in a south-easterly direction from the Silakank stream to the Milam passes, and which forms the north-eastern buttresses of the Dunagiri and the Nandadevi, all bear a cap of carboniferous rocks, resting on a base of older palæozoics.

The highest part of the range east of the Kharbasiya gorge, the Marchauk and Hóti peaks, consists of the highly coloured upper carboniferous beds, and a zone of the *Coral*-limestone (6) crops up below it, shown both on the map and the sections 2 and 3, pl. 3. I found that the *Coral*-limestone (6) with its base has suffered so much by contortion, jointing, and faulting that it would have been impossible to record graphically all the detached portions of the formation in the rugged and snow-covered area of enormous peaks. The lines in the map, of course, illustrate the distribution of rock-zones only diagrammatically.

Fossil traces are distributed throughout this formation, though good specimens are rarely met with in the Niti area.

Chór Hóti and Painkanda.

The Chór Hóti section (3 in pl. 3) is again perhaps the most favourable locality for fossils; nearly every fragment of weathered debris found on the hill slopes contains traces, but mostly in a very bad state of preservation. The lower part of the steep cliff which forms the last ascent of the Painkanda peak (19,340′), is composed of the dark-blue concretionary *Coral*-limestone (6) of the devonians.

Girthi Valley.

In the Girthi valley I found the limestone (6) close to the Girthi camping ground at the base of a high snow-covered peak (20,344′), composed of the upper carboniferous rocks; the *Coral*-limestone (6) dips about 40 to 45° north-east below the red *Crinoid* limestone (7), of the upper carboniferous which forms the high cliffs through which the Girthi river has eroded its bed at that spot. It is part of the great north-west to south-east zone, which though easily traced by its distinctive colour, I could only cross at a few places; the Rimkin sections (see pl. 2, pl. 10, and sect. 3, pl 3), those of the Girthi valley and lastly the Milam sections show clearly the same sequence of formations.

Carboniferous; red *Crinoid* limestone (7).

The steep cliffs on the right bank of the Silakank stream are all capped by very conspicuous beds of densely red to red-brown limestone (see pl. 6), which rests on the *Coral*-limestone (6) of my sections.

Both this division and the overlying white quartzite (8) vary much in thickness. In the Niti area I have found its thickness from 350 to 500 feet and is there very uniform in lithological character. Generally it is an earthy limestone of a brick-red to brown colour, in beds of 6 to 12 inches in thickness, with occasional masses of almost unstratified limestone with silicious concretions. Shining plates of *Crinoids*, and now and then perfectly preserved *Encrinite* discs are scattered throughout the rock. Other fossils are rare and badly preserved,—usually in casts only, amongst which an *Orthoceras* species is commonest.

I found the upper boundary of the formation not well defined; the

White quartzite (8).

red *Crinoid* limestone is thinner bedded, and is partially alternating with white quartzite beds near the boundary.

The latter division is exceedingly variable in thickness, from 350 feet in the Silakank sections, to 600 and 800 feet further south-eastwards. It is generally a pure white sugar-grained quartzite, almost resembling white marble in texture, and I found it in most localities forming very thick massive beds, which become rather more flaggy towards the top of the division. Both the *Crinoid* limestone and the white quartzite show a great deal of local disturbance in the shape of minor faults and jointing.

I found several badly preserved fossil remains in the quartzite but was not often lucky enough to be able to extract them from the solid hard rock. On the weathered surfaces of the white quartzite casts of *Orthis* sp., *Orthoceras* sp. are rather common.

Marchauk pass best section.

The best section in the Niti area, which shows the *Crinoid* limestone (7), and the white quartzite (8), is perhaps the Marchauk one; there the small glacier, over which the final ascent to the pass leads, passes through the upper carboniferous rocks. The sides of the glacier valley are composed of the red *Crinoid* limestone (7), whereas the precipitous cone on the right (south) side of the pass 19,518′ high, consists of the white quartzite (8). It is a most conspicuous, and I believe inaccessible peak, not unlike the Matterhorn in general outline. The moraines of the small Marchauk glacier are all composed of angular fragments of upper carboniferous rocks, the red *Crinoid* limestone conspicuously showing amongst the pure white quartzite.

Hóti peaks.

About two miles south of the Marchauk the Hóti peaks (18,457′ and 19,228′) project their steep cliffs from amongst a covering of eternal snow; their highest ridges and peaks consist of upper carboniferous rocks, the densely red *Crinoid*-limestone (7) resting on the dark-coloured *Coral*-limestone (6), and is capped by the white quartzite (8), the latter weathering a rusty brownish yellow.

The towering precipices which rise on each side of the Chór Hóti pass are, as far as I could examine them, composed of the easily recognized white quartzite (8).

Silakank pass.

Returning from Tibet by the Silakank pass, I descended (moving almost due west) over the beds of the rhaetic and trias beds, which (with their lowest permo-trias members) I found to rest on the upper carboniferous. Without any difficulty one may trace the latter along the face of the high cliffs on the right side of the Silakank stream resting on the devonian *Coral*-limestone (6), and with the underlying silurians forming one great palæozoic group, structurally closely connected throughout.

The projecting nose, or headland, near the junction of the Dhauli Ganga and the Silakank stream shows a good vertical section through the palæozoic group (see profile, pl. 6).

White quartzite wanting in some sections.

The white quartzite (8) suffered probably a certain amount of denudation before the subsequent black *Productus* shales were deposited, and consequently the upper boundary of the quartzite exhibits at some places a rugged and denuded surface, and is altogether wanting in one or two localities in the Niti area. This is the case on the left side of the Dhauli Ganga, north of Patalpani, where the white quartzite (8) is partially wanting, the black *Productus* shales (9) resting immediately on the red *Crinoid* limestone (7).

Kiunglung and north-west of it.

Near Kiunglung, on the south slope of the Niti pass, the sequence of the carboniferous is quite normal, see figs. 16 and 17), and the white quartzite (8) is strongly developed.

I was able to trace the quartzite over the broken hills far to the north-west below the snow-covered peaks west of the Niti pass, and found that there its upper beds alternate with some impure hard limestone, containing some well-preserved fossils, amongst which *Brachiopods*, chiefly *Producti*, are commonest. The carboniferous series dips 37 to 40° north-east, and is conformably overlaid by the permo-trias of the Niti pass.

The Girthi river with its tributary, the stream which drains from Hóti and Rimkin, has excavated a deep ravine, through the entire trias beds, and down into the upper carboniferous, which along a considerable distance in these river-valleys forms the high cliffs bounding the stream gorges. I have shewn this feature in pls. 2 and 3; the white quartzite (8) is especially conspicuous and forms precipitous cliffs. Some fossils, chiefly *Orthis* species, were found in the Girthi valley in the white quartzite (8).

The lower mesozoic group in Niti. Structurally connected.

The beds which are enclosed between the upper carboniferous and limestones with fossils of triassic type form by far the most interesting of the Himálayan strata; I have been able to study this succession of strata somewhat closer than the rest of the rock groups. Several of the divisions which form the group are so characteristic, lithologically, besides always yielding the same easily recognized types of fossil remains, that they have served as landmarks, as it were, to make out the often very difficult structure of these hill-ranges. And this has been the case from the Nepál frontier to Spiti; season after season I could identify the same old acquaintances amongst the chain of beds. Often, in an area nearly entirely snow-enshrouded, in altitudes where prolonged work or careful search for fossils would have been impossible, isolated bare patches, revealing one or more of my type beds, have enabled me to fit in with sufficient accuracy areas and boundary lines of divisions, where otherwise I would have been obliged to leave a blank.

The Niti area was the first where I could study in detail the permo-triassic rocks. As detailed in the general description of this group, it forms one sequence of beds, from the black *Productus* shales (9), to the light-coloured triassic strata at the top of the group. Not a trace of unconformity could be detected throughout the great thickness of strata, though the lithological features of the various systems constituting the group is often very varied, indicating a great change in physical character of the seas which must have deposited them, which is indeed also borne out by the fossils found in them. But, notwithstanding, no unconformity is found throughout.

Rests on partially denuded carboniferous rocks.

As I have described in the general chapter on this group, the relations of it to the underlying rocks varies in the different sections which I have examined. Whilst in Spiti a gradual passage was observed from the carboniferous white quartzite (8) into an overlying *Productus* limestone, which in a lesser degree I also noticed in the most eastern sections of Kumaon. I found that in the Niti sections the *Productus* shales (9), part of which are here missing, are resting directly upon a partially denuded surface of carboniferous rocks. So marked is this feature, that when I first visited the locality in 1879, I failed altogether to notice that a zone of *Productus* shales exists at the base of the lower trias.

Silakank section.

In the Niti area, *i.e.*, south-west of the watershed between the Dhauli Ganga and the Húndés drainage, it is again the steep, but not inaccessible, south-western slopes of the range, which runs from the Marchauk pass in a more or less north-westerly direction towards the head-waters of the Shanki river, and in which the Silakank peaks and the Niti pass are situated, which offers the most complete sections through the entire group. Viewing this range from the north-western slopes of the Chango (Patalpáni, Gwelding, etc.), one may notice a black band of not very great thickness, sharply contrasting with the rocks below it, which are generally the white quartzite (8) of the upper carboniferous; the latter, however, thins out towards the north-west, and then the black band rests on the deep-red *Crinoid* limestone (7) of the upper carboniferous.

This black band may be traced far away into the ragged and mostly snow-covered, and very difficult area of the Upper Ganes Ganga. It is everywhere visible from afar off, more resembling the outcrop of a coal-seam than any other rock.

Unconformity.

After my second season in the Himálayas, when I observed the *Productus* shales resting conformably on the upper carboniferous in Eastern Kumáun, I felt inclined to look upon the apparent unconformity between the carboniferous and the *Productus* shales in the Niti sections as due to

crushing only; in a disturbed and folded area, such as the Himálayas, it is a common feature to find, where friable and yielding shales are enclosed between more rigid strata, the first crushed often beyond recognition, as the uppermost rigid stratà are pushed over the underlying beds. But a subsequent second visit to the Niti area in 1883 convinced me that here I had not only local crushing to account for, but that the *Productus* shales really rest on an eroded surface of the upper carboniferous. Particularly in the Silakank sections it is seen how uneven and often deeply eroded the white quartzite (8) is, whilst the dark *Productus* shales rest in normal order on this rugged base of upper carboniferous rocks. The strata immediately underlying the *Productus* shales are the massive beds of the white quartzite in the valley of the Silakank stream, but further north-west along the slopes which overhang the Dhauli Ganga, I noticed the permo-trias group overlapping the red *Crinoid* limestone,—the white quartzite having quite disappeared.

Kiunglung.

Some few miles further north, between the Kiunglung camping ground and the range which forms the frontier between Garhwál and Húndés, the white quartzite, with beds of a gritty calcareous sandstone, and earthy limestones, appears in great thickness below the *Productus* shales. The overlap of the *Productus* shales over the carboniferous beds in the Niti area offers good evidence that considerable physical changes must have occurred near the close of the carboniferous period. The lithological characters of the various divisions and strata of the lower palæozoic formations are so strikingly uniform in the whole area examined by me, that the sudden irregularity, the considerable variations and partial overlaps, which occur within the shortest distances near the boundary between the Upper Carboniferous and the *Productus* beds, clearly indicates considerable changes in the character and in the outlines of the coast of this period.

I observed that the general characters of the beds of the permo-trias do not on the whole differ very much from those of this group in other sections, with the exception of the lowest and uppermost beds

composing the same. The lowest member of the group is only partially represented in the Niti sections, and the uppermost beds have a distinctly local character.

Trias.

The triassic rocks are found along the range which runs from the Marchauk pass to the Niti peaks. The range presents a steep scarp towards the south-west, along which the entire thickness of the various divisions is exposed. Profile, pl. 6, gives a view of this range, and shows the approximate thicknesses of the various divisions composing it. The individual beds seem to remain very constant in lithological character in all the sections which I examined. Indeed, the beds are nearly everywhere entirely exposed to view, and may be seen and recognized a long distance off.

From the Silakank to Pethathali.

One of the routes from Húndés leads over the Ma Rhi La (pass) through the pastures of Bára Hótí to the Dhauli Ganga valley by the Silakank pass. It is a very rough and seldom used path. After crossing the Sílakank the track descends the Silakank stream to its junction with the Dhauli Ganga, which track is only passable to lightly laden sheep and goats. The Silakank pass itself is formed of typical rhætic and trias beds. The south and south-east flank of the pass are composed of the uppermost rhætic, a dark-blue limestone, weathering a bright sienna colour, dip about 30° south. They contain fossils typical of the upper rhætic horizon, and are intercalated between beds of calcareous sandstone and shales, all containing Kœssen fossils. It is the region immediately adjoining the great fault which runs from the Niti heights along the frontier, and the cleavage, which the upper rhætic beds show near the fault in a most pronounced degree, must be ascribed to the enormous lateral pressure which they underwent, when being pushed out of their normal position by faulting. In places the original bedding has been almost entirely obliterated. In addition to this the section is obstructed by enormous masses of debris, which issue in wide fans from every ravine. Near the top of the pass itself, I met pink and reddish limestone beds with some

bright orange-yellow bands. All are more or less dolomitic, and show a cellular (Rauchwacke) structure, but they contain beds of true *Lithodendron* limestone, in which the white sections and the structure of this fossil are clearly weathered out of the darker rock.

In descending the pass into the valley of the Silakank, I crossed in succession the up-turned strata of dark limestones and dolomites with marly intercalations, of the rhætic system ; fossils abound, and near the base of the great slope, dark, rust-brown limestone with shaly partings crops out below the rhætic dolomites, in which casts of *Corbis* sp. are common. These are the upper triassic limestones, met with in the typical sections of Shal Shal (p. 135). The beds gradually assume a normal north-west to south-east strike with a north-easterly dip of about 30°. Below the upper trias limestones with *Corbis* sp. I found the entire middle and lower trias in which dark-coloured limestone and dolomites predominate, but the greater part of the trias in the slope from the Silakank pass to the stream-bed is hidden by enormous accumulation of debris ; however near the bottom of the valley I found a portion of the section protruding from below this undercliff which consisted of the lighter coloured grey hard limestone, yielding middle trias (Muschelkalk) fossils. A few hundred feet below it the carboniferous white quartzite forms steep cliffs on both sides of the valley. But lower down towards Pethathali the section is somewhat clearer of debris, and I noticed the permo-trias group rest on the eroded surface of the upper carboniferous. From the edge of the cliffs formed by the latter the trias and rhætic section rises in one continuous series to the jagged cliffs of the Silakank ridge. (See Profile, pl. 6).

Niti pass. Kiunglung Permians.

The camping ground at the foot of the Niti pass about a mile above Kiunglung is on carboniferous strata. The red *Crinoid* limestone (7), see fig. 17, is in great force associated with a calcareous grit, and beds of sandstone of reddish-grey colour. The whole formation dips about 60° to north-east, and is overlaid by a considerable thickness of the white quartzite (8) into which the red *Crinoid* limestone (7) passes through grits and sandstone.

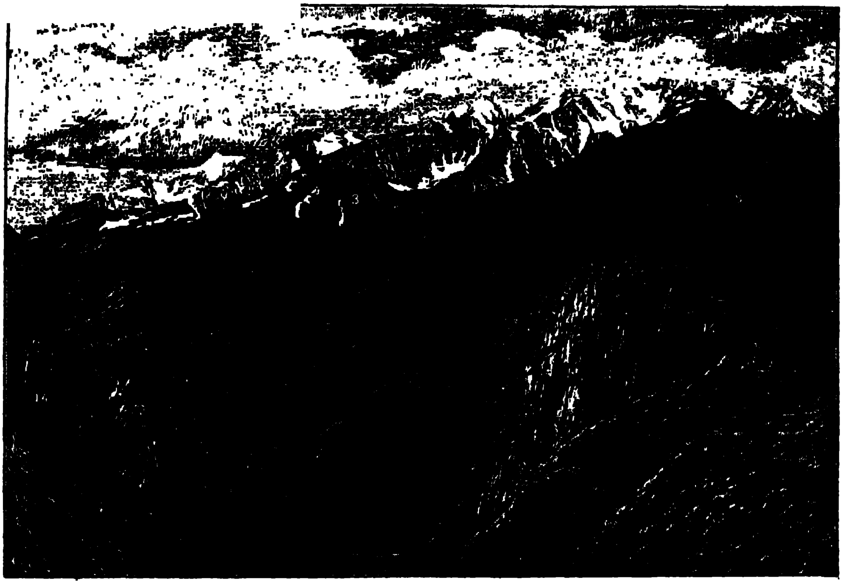

Fig. 17. The Daldakharak from the Niti pass.

On the weathered surfaces of the white quartzite (8) sections of shells are plentiful, amongst which an *Orthis* species seems commonest. Higher up in the ravine which joins the Dhauli Ganga from the right, at the foot of the Niti pass, I found the red *Crinoid* limestone (7) full of *Productus* sp., *Athyris royssii*, etc. The white quartzite, which is in enormously thick banks near the middle of its thickness, becomes more flaggy near the top, and the beds are then a quartz sandstone, finally developing into a calcareous thick-bedded dark grey sandstone full of *Productus semi-reticulatus*. I have compared both the specimens and the matrix with specimens contained in the Geological Survey Museum, which had been collected at Kuling by Dr. Stoliczka; both are so close in form and lithological character that they might easily have come from the same locality.

Near Kuling and Muth in Spiti I found the white quartzite (8) overlaid by a series of beds, containing *Productus* sp. in turn conformably followed by a considerable thickness of the dark *Otoceras* beds. But here in the Niti sections, the *Productus* shales which are closely

connected with the next following beds with *Otoceras*, dwindle down to only fifty feet, and rest immediately on the white quartzite (8) in the Silakank ravine, on the red *Crinoid* limestone (7) in the upper Dhauli Ganga gorge, and on the *Productus semi-reticulatus* sandstone and white quartzite in the Kiunglung ravine.

Further on and as far as the top of the Niti pass follows a normal sequence of the trias and rhætic, the base being formed by friable black shales, with partings of ferruginous nodular clay bands. One or two partings in this zone, the thickness of which scarcely exceeds 50 feet near Kiunglung, resembles closely the dark grey micaceous sandstone below, which I could identify later on with the typical Kuling beds of Stoliczka. The black shales of Kiunglung yielded only crushed specimens of a *Productus*, which I think is nearest allied to the *Productus latirostratus Howse*. During my first visit to Niti I altogether failed to distinguish this zone from the *Otoceras* beds above, with which they are almost identical in lithological characters; I therefore understood it to form one single division with the 130 feet of shales and limestone above it. However, a subsequent visit to Spiti convinced me of my mistake, which indeed had already been pointed out by Lydekker, and when I again examined this section near the Niti pass in 1882, I found that these 50 to 60 feet of dark crumbling shales represent the uppermost portion of the more extensive Upper Kuling beds of Spiti, and must therefore be separated from the *Otoceras* beds. As they are unconformable to the carboniferous below, and moreover form with the trias a connected group, I am inclined to look upon this *Productus* shale division as the representatives in the Central Himálayas of the permian of South-Eastern Europe.

Otoceras zone (10). Lower trias.

The lowest horizon of the trias consists of a succession of hard black limestones, alternating with crumbling dark shales which closely resemble the beds below. Both shales and limestone have yielded many good fossils, amongst which occurs the leading form of *Otoceras* as already pointed out in the general description of this horizon; it represents a passage bed from the permian into the lower trias, and is of great geographical distribution.

Above it follows the uninterrupted series of strata of the lowe, middle and upper trias overlaid by a great thickness of the rhætic system. The path which ascends the Niti pass runs through a dry ravine (fig. 17) during the lower half of the ascent, and exposes the beds well. The lower portion of the triassic beds (all yielding fossils) are greatly disturbed and there is considerable local crushing. But nevertheless the general sequence is seen to be the same as in the measured section of Shal Shal (page 138ff). On the *Otoceras* beds follow hard grey limestones with Muschelkalk species, which are overlaid by hard black splintery limestones and shales with traces of fossils only. The upper portion of the triassic system is formed by a light grey hard limestone in thick beds, with rust-coloured flaggy limestone beds, on which immediately follows the great thickness of thick-bedded limestones and dolomites which I consider to belong to the rhætic. The bottom bed of it is a pink and variegated coloured cellular limestone seen in most sections near the base of the rhætic. In the middle portion of the rhætic, rather more than half way up the Niti pass, beds with many fossils of Koessen type are seen. Higher up another parting in the dolomite series, in which sections of *Megalodon* sp. are frequent, appears, in which *Belemnites* crumble out in fragments. This bed, a dark shale with partial oolitic structure, I have also noticed near Bara Hoti at the foot of the Ma Rhi La (pass).

Middle and upper trias of the Niti pass.

Rhætic.

Sections north of the Niti pass.

The top of the pass is formed of beds with *Rhynchonella* sp., *Terebratula* sp., etc., and on the top of it is piled an enormous thickness of light-coloured limestones with bright reddish beds and nodular intercalations. They are seen to form the cliffs on each side of the pass, stretching far away towards the jagged points of the Silakank south of it.

Lias.

Mere fragments of fossils picked up in these great heights show that this portion of the limestones must be looked upon as liassic. Many of the fossils contained in it are of liassic types, whilst others

belong to the Starhemberg facies of the Koessen beds; but, on the whole, I agree with Stoliczka that this horizon must be looked upon as belonging to the lias, or as Stoliczka calls it, the Tagling limestone. The beds dip some 40° to north-east, descending in great weather-worn sheets down to the Shanki river, where they dip below the jurassic Spiti shales. They form the rugged ridge and highest points of the Silakank range, where they are much disturbed by local crushing.

The section of the Niti from Kiunglung to the top of the pass is therefore as follows, in descending order:—

Numbers in Sections.			Thickness in feet.
16	Lias	Thick limestone beds with partings of oolitic structure; fossil traces of liassic types	250
	Passage beds rhætic or lias.	Impure limestone with upper Koessen? fossils chiefly brachiopods . . .	50
15	Upper rhætic	Limestone beds with *fucoids*; partings of beds with Koessen fossils; higher up strong dolomites with casts of *Megalodon* sp.	500
14	Lower rhætic	Dolomites in thick beds with limestone flags	1,500
13	Upper trias	Brown limestone beds with shaly partings .	800
		Black splintery limestone and dolomites with shaly partings	500
12		Dark coloured flaggy limestone, with *Daonella* sp.	200
11	Middle trias	Light, grey concretionary limestone, with Muschelkalk fossils	60
10	Lower trias and passage beds.	Black shales, alternating with dark limestone, with *Otoceras Woodwardi*, etc. .	130
9	Upper permian	Black shales, with *Productus lati-rostratus* Howse var.	50
		Total thickness .	4,040

The sections from the Niti pass in a north-easterly direction pass over a succession of strata from the lias to post-tertiaries. The deep ravines which the tributary streams of the Sutlej have excavated afford admirable profiles.

From Niti to the Sutlej.

As I said before, the hard limestones and dark shales, which form the uppermost strata overlying the upper rhætic of the Niti pass, descend in more or less broken and jointed masses, often deeply eroded, down towards the north-east, dipping invariably below the black Spiti shales.

Two streams, the Shanki from the west, and the Sherik from the south, drain the Niti and Silakank peaks on the northern slope, and have excavated deep gorges (figs. 18 and 19) through the various rocks through which they pass in succession. These streams run as

nearly as possible at right angles through the beds of the lias and superincumbent Spiti shales.

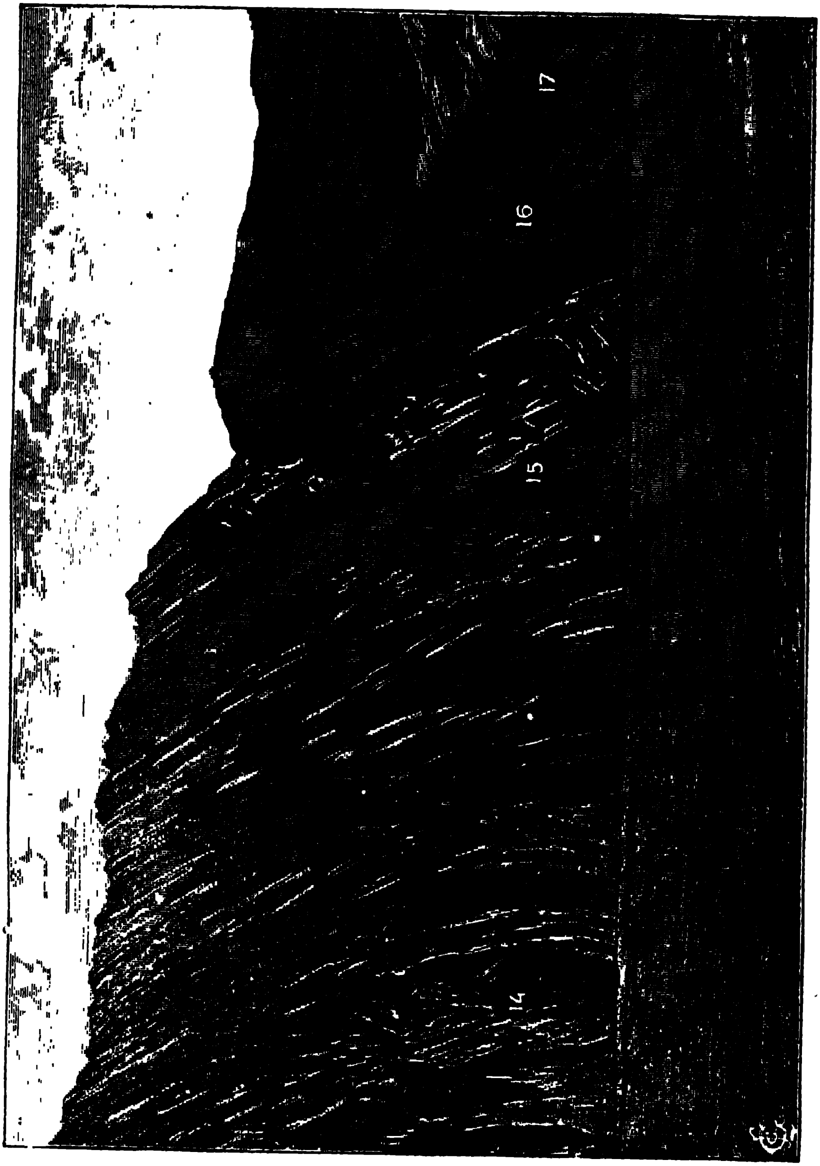

Fig. 18. Rhætic section of Shanki river, Húndés.

The Shanki river cuts in its upper course through the entire thickness of the lower (14) and upper (15) rhætic dolomites and limestones, and the overlying light-coloured lias limestone (16), with its dark fossiliferous shales. The beds dip under a high angle to the north-east (about 55°), and near the point where the direct road to Gartok crosses the Shanki river (fig. 18) is overlaid conformably by Spiti shales (17). The hard-grey limestone of the lias is full of fossils, amongst which a smooth *Gervillia* is most conspicuous, covering hundreds of square yards on the weathered surfaces of the limestone beds.

About three miles lower down the valley, which becomes more open after its entry into Spiti shales, the beds are rather disturbed and some faulting has taken place. The section from upper rhætic through the liassic limestones into Spiti shales is repeated.

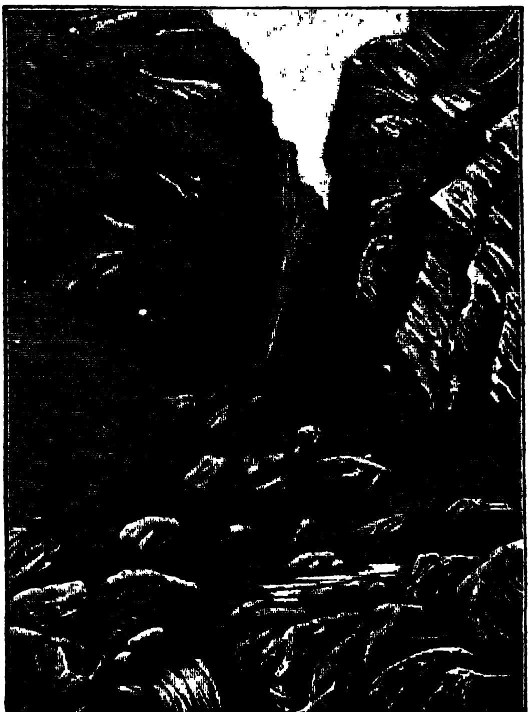

Fig. 19. Gorge through upper rhætics, north of the Niti pass.

The Sherik river has deeply eroded through the great sheets of liassic limestone, and reached the upper rhætic dolomites and limestones. A most picturesque gorge (fig 19) some four miles above the junction of the Sherik stream with the Shanki river shows the sequence of the upper rhætic and liassic strata, though the whole is greatly shattered and disturbed. The white sections of *Megâlodon sp.* in the dark dolomites, and higher up the *Lithodendron* weathered out in the dark rock clearly indicate the horizons. The liassic system is defined by its stratigraphical position between the upper rhætic beds with *Brachiopods*, and the fossiliferous Spiti shales. The lower beds of the lias consist of light-coloured grey limestones, weathering a rusty sienna colour; near the upper beds, a zone of dark calcareous shales with oolitic structure has yielded some fossils, chiefly *Ammonites*, and many *Belemnites*. This bed I have also met with in other sections, as for instance near the top of the Niti pass, and near Bára Hóti east of the Silakank. It is in all sections overlaid by a gritty grey limestone or calcareous sandstone with many fossils, chiefly *Bivalves*. The contact bed between the upper lias and the Spiti shales is a coarse conglomerate, chiefly made up of fragments of triassic and rhætic limestones.

The section through the lias is therefore in descending order: overlaid by Spiti shales.

3. *Gervillia* limestone.
2. Dark calcareous shales, oolitic structure, fossils;
1. Flaggy limestone, light grey in colour; great thickness;

The Spiti shales form low undulating ground north-east of the steeply inclined limestones of the lias, and may be recognized from afar off by the dark colour of the rounded outlines of the hills. The contact rock I found to be a coarse conglomerate formed of the limestones of the underlying beds. On it followed about *1,350 feet* of Spiti shales. The lowest portion of the latter is very ferruginous and yielded no fossils. Higher up the shales contained many nodules, nearly all of which enclosed fossils, chiefly *Ammonites* of middle jurassic types. Above this horizon, *Ammonites* become scarcer, but the nodules furnished

Spiti shales, north of Niti pass.

many specimens of *Modiola sp.*, *Posidonia sp.*, *Rhynchonella sp.*, followed, higher up (down the river) by shales which yielded nodules filled by *Belemnites sp.*, whole beds being made up of this fossil. After this *Ammonites* come in again, mostly of upper jurassic types. Throughout the whole thickness the lithological character seems to remain very similar, and it would be impossible to sharply define any of the divisions which pass from one into the other quite gradually.

Near Sirkia.

A very fair section of the Spiti shales is seen near the Sirkia encamping ground (fig. 11) to some ten miles lower down the Sherik river, and on the road to Dongpú in the province Húndés of Tibet. About a mile south of this camping ground, I again observed a small reversed fault, which has thrown the rhætic and lias beds against the Spiti shales; they dip about 35° (though locally much disturbed) to north-east. The section through the older beds is much the same as I found it higher up the river, namely, the bed exposed near the base, is a hard dark-grey limestone with many white calcspar veins crossing and recrossing it in every direction in which the shaly partings contain *Brachiopods* of upper rhætic or liassic type. On it follow limestones, very little, if at all different from those underlying them; on it rests a thin zone of dark earthy and oolitic shales which yielded chiefly *Belemnites*, overlaid by from 70 to 100 feet of a very hard light grey limestone with reddish irregular blotches, which contains numerous fossils, very difficult to extract from the hard matrix. Chiefly *Bivalves*, amongst which a smooth *Gervillia* is very conspicuous; these upper limestone beds belong evidently to the lias (Tagling series of Stoliczka).

The Spiti shales overlie this conformably, beginning with a characteristic contact bed of a conglomeratic breccia, made up of fragments of liassic rocks. It suggests a partial break or a change of coast line after the deposition of the liassic limestones, though the Spiti shales rest apparently conformably on the lias. Indeed such change is also suggested by the sudden appearance of soft black earthy shales after an uninterrupted series of limestones.

I measured the section of the Spiti shales of the Sirkia area as 1,350 feet, though I believe the actual thickness to be less. There is a good deal of local crushing, and in the soft friable mass faults are not easily detected or can be allowed for.

Thickness of Spiti shales near Sirkia.

The general sequence of beds is much the same as previously observed in the Sherik river. In the lowest portion I found numerous *Ammonites* in the nodules, chiefly *Triplicati*, *Bifurcati* and *Coronati*. Above follow nodules with many *Belemnites*, sometimes whole nests of them. *Posidonia* and other *Bivalves* also are numerous. This portion of the shales is again overlaid by a horizon in which the nodules yielded chiefly *Ammonites*, but the shales were getting gradually less rich in fossiliferous nodules and more ferruginous. Partings of clay iron ore, and strings of ferruginous concretions become common. Near the camp in the upper portion of the Spiti shales, fossils disappear almost altogether, or are only preserved as crushed fragments. The shales are now more evenly bedded, some portions intensely black, then again showing numerous ferruginous partings, between which the shales are dark grey, mostly micaceous, and not unlike some of the Gondwana shales in lithological appearance.

Cretaceous of Sirkia.

About 500 yards north of the camp, close to the junction of the Sirkia with the Sherik streams, high cliffs face southward (see fig. 11). They are formed of beds dipping about 35° north-east. The Sirkia river has excavated a narrow and very picturesque gorge through these beds and so exposed a perfect section of them. Near the junction of the two rivers the upper Spiti shales are beginning to alternate and pass into a thin bedded grey sandstone, the strata of which vary from 4″ to 8″ in thickness, become gradually more silicious, until near the base of the high cliffs north of the Sherik river it is a grey quartz sandstone, weathering a rusty brown, alternating with silicious greenish shales, which higher up again pass into a flaggy greenish grey quartzite. This rock continues northward through the gorge of the Sirkia

stream, steadily dipping north east. I did not get to the northern end of this gorge, though I viewed it from afar. The total thickness of the formation may be from 1,200 to 1,500′. About half-way up the section I came across a bed, in which calcareous concretions yielded a few crushed *Belemnites*. Otherwise this system has not yielded any fossils. Its age I believe to be either lower cretaceous or upper tithonian; being enclosed between the upper jurassic Spiti shales and upper cretaceous limestone as I found to be the case in other sections, it could not be anything else.

Section between the Niti pass and Dongpú.

Instead of continuing the route from the Sirkia to the Sutlej, I crossed the Húndés plateau between the Sirkia river and the Nükchung stream to Nábgo above Dongpú, and obtained a fair section of the tertiaries of Húndés by so doing (see plate 12). The valley of the Sutlej is in shape an elevated basin, inclosed by the crest of the Himálayan watershed and the snow-capped Kailás range, the watershed between the Indus and Sutlej. East of the Manassarawar lakes, a watershed range divides the valley of the Sutlej from the headwaters of the drainage of Eastern Tibet. The area of this basin is partially filled by tertiary deposits, the uppermost and horizontal beds of which cover all the older rocks and creep up the high slopes both of the Himálayan ranges and of the Kailás hills. The mean altitude of these beds near the centre of the basin is about 14,000′ above the sea-level. But after exploration it is seen that the seemingly uniform plain (pl. 12) is in reality deeply eroded by the Sutlej and its numerous side-streams, which cut down through all the tertiary strata and expose even the younger mesozoic rocks below the latter. These valleys of erosion form generally deep V-shaped troughs and narrow gorges. The Sutlej gorge, where it widens here and there, is the only part of Húndés which may be said to be inhabited. The strip of watershed between each of the tributaries of the Sutlej, as, for instance, between the Sirkia and the Nukchung streams, is formed by upper tertiary beds, which had once uniformly covered the entire basin of Húndés. Below them crop out the older rocks from the Spiti shales

to the freshwater sandstone and gravels seen near Dongpú, which I believe to be older than the Húndés ossiferous deposits.

When I crossed into the Nukchung valley from the Sirkia stream, I did so near the boundary between the Spiti shales and the cretaceous sandstones. The Nukchung valley forms a narrow trough in the cretaceous rocks; sandstones and gritty shales with hard quartzitic grits, all more or less of a dirty green and brownish green colour dip to north-east. But there is so much of local disturbance and faulting that it would be impossible to do more than roughly estimate the thickness of the entire division; it may be from 1,200 to 1,500′ in thickness. About a mile south of the Nabgo encamping ground, the gorge narrows considerably, and I found white limestone full of bivalves (*Inoceramus sp.*), which I take to be upper cretaceous (Chikkim limestone of Stoliczka) conformably overlying the sandstones below. It is here of very inconsiderable thickness, certainly not more than 150 to 180′, and is further on followed by some 300 to 400′ of a singular rock. This is a densely hard, dark-red and purple silicious rock, with some layers of what appears like highly altered clay shales, and talcose schists. With it appears a dark basaltic rock, and the whole is greatly disturbed. But nevertheless what bedding is left is seen to be conformable to the upper cretaceous limestone. Fortunately after a long search I found some strangely contorted specimens of *Nummulites* in a calcareous portion of the altered rock, which I believe will be found to correspond to the *Nummulitic* zone described by Stoliczka from the Upper Indus, altered by a post-eocene eruptive rock; the latter must be the basaltic trap which disturbs the formation, and I believe the albite granite and syenite, which has played such an extensive rôle amongst the younger rocks of the Himálayas and the Perso-Áfghán ranges, may be of nearly the same period. Near Nabgo encamping ground the altered *Nummulitic* limestone associated with basaltic rocks is well seen, especially near the left side of the valley and in the gorge just north of the camp.

Between Nabgo and Dongpú the conformity which prevails throughout the mesozoic and older tertiary rocks suddenly ceases. I

found a coarse sandstone resting unconformably on the altered *Nummulitic* rocks. It is a grey sandstone of the pepper-and-salt colour common in the Siwaliks, in thin banks, divided by shaly portions of the same, and partings of gritty conglomerate. I found no traces of organic remains in these beds. They are unconformably overlaid, and lost under masses of younger deposits near Dongpú. Probably the deeply eroded Sutlej valley would show better sections of this formation, but I was not allowed to descend into it.

One feature is plainly seen. The sandstone, which cannot be older than miocene, and which must correspond to one of the Siwalik horizons, has a rolling dip to north, and shows a great amount of erosion. The upturned edges of the sandstone beds are deeply eroded into, and the whole is evenly capped by younger deposits. Conglomerates, grits, soft friable sandstone and clays rest horizontally alike over this sandstone and the older beds below. The total thickness of these deposits cannot be under 350 to 400′ near Dongpú, but is probably much more near the centre of the basin. As already described in the chapter on the tertiaries of Húndés, these horizontal deposits contain occasionally remains of *Mammalia*, of which a few fragments were excavated by Sub-Assistant Lala Kishen Singh, near Dongpú.

Eastern Painkanda and Johar.

Directly east of the Niti area extend the districts of Eastern Painkanda and Johár, which I found most difficult ground: Were it not for certain characteristic horizons, that tract could scarcely have been explored.

Although the map of this area presents a very variegated appearance, and seemingly shows an irregular distribution of the various formations, yet there is the same system of flexures met with in each one of the cross-sections. The belt of sedimentary rocks which runs from north-west to south-east may stratigraphically be divided into three strips; the palæozoic one, the trias-rhætic and the younger mesozoic, which runs along the Himálayan-Tibet frontier. During

the process of folding which the Himálayan rocks have undergone, the rocks of the permian and lower trias have suffered the greatest amount of contortion, chiefly perhaps, because the softer rocks, shales and thin-bedded limestones of the lower and middle trias have yielded to side-pressure much more than did the rigid dolomites and limestones of the rhætic. They are found to generally occupy a narrow synclinal strip inclosed between one or more great anticlinals. Similarly, the Spiti shales frequently are found crushed into a narrow synclinal between the trias and upper rhætic. The palæozoic rocks, which form the zone nearest the metamorphic centre, generally are seen as one or more gigantic anticlinals.

The fault (see sections) which I have described as running in a north-west to south-east direction from the Dhauli Ganga to the Milam passes, may be traced almost without interruption and is seen to lose itself near the Uttardhura pass, where the throw is quite insignificant.

Bára Hóti Section.

In the section between the Marchauk pass and the Ma Rhi La, the palæozoic rocks are seen east of the former pass, to dip about 45° towards the triassic system, which has been let down by the great Painkanda fault to below the level of the palæozoic rocks. The latter consist there of the flesh-coloured quartzites and green shales of the upper silurian, overlaid by the carboniferous, whilst the white quartzite (8) crowns the jagged peaks of the Marchauk. Further to the south-east, however, I observed the lowest silurian *coral*-limestones with fossils to underlie the upper silurian shales and quartzites, and to form with them a great anticlinal arch at the Chór Hóti pass; near the small glacier north of it the beds are very little inclined towards the east, whereas further away from the centre of the arch, and in the proximity of the fault, the beds have a dip of 50° and more to the north-east by east.

The whole east slope of the Marchauk and Chór Hóti range is obscured by masses of debris and moraine matter, but numerous deep ravines have been scooped out through the talus down to the rocks

in situ, and as the streams all run nearly at right angles to the strike, they have exposed good sections.

The track from the Marchauk to the Bára Hóti grazing grounds leads along the ridge of one of the great fans which descends from the pass eastwards. A ravine cuts through this fan north of the path and finally runs into the Shal-Shal river. It exposes a good section through the middle and upper trias. I found in descending order:

Concretionary brown limestones of great thickness, which rest conformably on—

> *d* Grey limestone in thick beds, with fossil traces weathered out on the surface; *Monotis sp*
>
> *c* Dark grey limestone beds filled with small *Bivalves*, which are closely united with the matrix.
>
> *b*. Several hundred feet of flaggy black limestone beds, alternating with splintery black shales. The latter yielded a few traces of fossils, *Terebratula sp* and *Ammonites*. This division is of most striking aspect, with the limestone weathering a dirty white, in strong contrast to the black shales; the latter increase in thickness towards the top of the series
>
> *a* Thick beds of very hard dark grey limestone, traversed by numerous calcspar veins. The upper beds especially are very massive, and I measured one more than 30′ in thickness. Fossils, chiefly *Cephalopoda*, are numerous, but almost impossible to chisel out of the rock, with which they are closely united. *Ceratites sp*.

The base of this section is hidden under masses of debris, but I observed above the brown limestone beds which overlie this section, the nearly vertical cliff of dark limestone and dolomites of the rhætic system rise towards the Silakank pass.

North-eastwards of the head of the Shal-Shal ravine one passes through an ascending section of the rhætic and trias beds, overlaid conformably by the black Spiti shales which, owing to the very uneven and rolling dip, swell out here to a band of considerable width and form part of the low ridge of the watershed in which the Ting Jung La and Ma Rhi La (passes) are situated; the higher parts of this ridge is formed by the greenish brown sandstones and shales of the lower cretaceous, which overlie the Spiti shales conformably.

This section is in descending order:—

Possibly Upper Tithon and Lowest Cretaceous.	Greenish-brown sandstone, with shales of considerable thickness, not less than 1,200′. They form high cliffs of somewhat irregular contour and a shallow synclinal, dipping about 20 to 25° inwards. They rest conformably on the beds below, the passage from which is gradual.
Middle and Upper Jurassic.	Friable black, to dark grey shales with concretions, yielding many 'Spiti' fossils. I could not estimate the thickness owing to the rolling dip, but they rest apparently conformable on the beds below.
	Gritty *Crinoid* limestone with many fossils, all of which are very small. *Pecten sp.*, &c.
Lias.	Dark shaly beds of irregular thickness, oolitic in structure and containing many fossils, though mostly in bad preservation. Mostly *Cephalopods* of liassic type.
	Limestone, thin-bedded, filled with *Crinoid* remains, and yielding numerous fossils of upper rhaetic (Koessen) type.
	Uneven bedded, hard *Crinoid* limestone, grey, of considerable thickness, with parting of earthy limestone yielding Koessen fossils.
Upper Rhaetic.	About 20′ of flaggy dark grey limestone.
	Grey papery shales, with numerous *Ostrea sp.*
	Flaggy grey limestone and shales with *Oyster* banks.
	Massive, dark grey dolomite beds, and limestone with sections of *Megalodon sp.* seen on the weathered surfaces.

The dark dolomites with *Megalodon* are the lowest beds seen in this section, exposed near the rise of the deep ravine of the Shal-Shal stream. The dip of the beds is here about 25 to 30° north-east, forming in fact an anticlinal, through the arch of which the Shal-Shal stream has eroded its deep channel.

West and north-west of Bára Hóti the ground is completely obscured by huge masses of debris, enormous fans stretching from the Silakank and Marchauk heights down towards the valley. But along the routes to both passes enough of the rocks are exposed below the debris where spring torrents have cut through the latter to show that the dip of the section is extremely rolling and uneven, and in the neighbourhood of the fault greatly crushed and disturbed. Nothing but rhætic beds, chiefly middle and upper ("Dachstein" and "Koessen beds") are exposed between Bára Hóti and the Silakank, whilst west of the Marchauk middle and upper trias are overlaid by the lower rhætic dolomites.

Shal-Shal Sections.

Much more instructive are the sections across the Shal-Shal valley further to the south-east.

As already observed, the Shal-Shal stream has eroded a deep gorge more or less along the strike of an anticlinal which is chiefly formed by trias and rhætic beds, followed on the eastern flank by younger mesozoic strata, and bounded on the west side by the great Painkanda fault. This anticlinal runs first to south-east near the upper course of the Shal-Shal gorge, gradually turns south and merges into the great dome-shaped mass of the Kurguthidhár, which is chiefly composed of the upper carboniferous white quartzite (8). The Painkanda fault cuts through this anticlinal and produces some crushing and local disturbance. But from the rise of the Shal-Shal stream to about four miles below Rimkin Paiar encamping ground, the stream has eroded through nearly the centre of the anticlinal arch and exposes in turns not only all the beds of the rhætic and trias, but also the upper and middle carboniferous, which are seen in parallel bands on each side of the valley, where they form precipitous but not altogether inaccessible cliffs. It is impossible to avoid the conclusion that the stream runs now in an eroded and widened fissure, caused along the axis of the anticlinal, along the line of greatest tension:

Section 3 of pl. 3 further illustrates the structure of the Shal-Shal valley. The Painkanda fault interrupts the continuity of the palæozoic section of the Chór Hóti ridge of peaks, and the down-throw to the north-east brings the rhætic beds of the Shal-Shal valley in immediate contact with the former. This feature is exceedingly well seen in a rocky ravine about a mile west of Rimkin Paiar, on both sides of which the structure is laid bare and the rhætic beds may be seen crushed against the fault line. In slipping down along an inclined plane the mesozoic strata had to accommodate themselves to a narrow trough, and thus were squeezed into an arched anticlinal, which possibly opening in a straight fissure along its ridge, gave first rise to the straight-running Shal-Shal stream, which afterwards eroded a deep gorge in place of the fissure. The down-throw is accompanied

by several minor faults running parallel with the great Painkanda fault, but they have not altered the general distribution of the various formations to any great degree. Section 3, pl. 3, runs across the Shal-Shal valley about half way between the camping grounds of Rimkin and Rimkin Paiar, and therefore only exposes the rhætic and upper trias beds. Lower down the valley, the whole chain of formations are seen from the carboniferous to the jurassic Spiti shales The river is at that point quite impassable, and I had to carry on my studies first on the Kurguthidhár side, and afterwards march round to Shal-Shal by the head of the valley. But the cliffs are exceedingly favourable for a correct measurement of the thickness of each individual bed, which process I carried out successfully.

Near Rimkin Paiar.

Near Rimkin Paiar I found the lowest bed exposed to be the white quartzite (8) of the upper carboniferous system. It is generally in massive thick beds, but towards the top it shows a few irregular thinner-bedded strata, amongst which a coarse, gritty, silicious sandstone is intercalated Lower down the stream, this white quartzite rests on the red *Crinoid* limestone with which it seems to alternate near the junction. At least amongst the red *Crinoid* limestone beds near the contact appear silicious flesh-coloured sandstones which alternate with thin beds of white quartzite, till finally the latter predominates. The white quartzite is about ;oo' in thickness near Rimkin Paiar, and beyond the appearance of an irregular eroded and jagged outline of the uppermost portion of the white quartzite, the following beds would seem to rest conformable on it.

Productus shales and lower trias of Rimkin Paiar.

About a mile south of Rimkin Paiar the *Productus* shales (9 in sections), and the lowest trias beds are particularly well exposed and the latter have yielded some good fossils. The thickness of the *Productus* shales is very insignificant, a little over a hundred feet, and beyond crushed specimens of a small *Productus* sp. have yielded nothing, but they are overlaid by the whole sequence of lower trias beds, between which and the lower *Productus* beds there is a gra-

dual passage. Most of the specimens of *Otoceras woodwardi* and *Xenodiscus* sp. were found in close proximity immediately above the *Productus* shales, whilst in the upper beds fossils become scarcer and other types set in.

They are overlaid in succession by hard grey limestones with Muschelkalk species, whilst above that division follow beds of the upper trias and rhætic.

The section on the western side of the Shal-Shal Valley is too much encumbered by slipped masses, and great fans of débris to allow measurements being taken, but this I could do easily on its eastern side, where a magnificent cliff (profile Plate 13) offered every facility for so doing. About 2 miles west of Shal-Shal camping ground I observed a small fault, and west of the latter Spiti shales, which rest on earthy dark shales of oolitic structure, containing amongst other fossils *Rhynchonella austriaca* Sss. associated with grey limestone, which yielded fossil traces of liassic type. Below that I found an uninterrupted, perfectly conformable group of limestones, shales and dolomites which represents the entire rhætic and triassic systems down to the *Otoceras* passage beds, and permian *Productus* shales which rest on an eroded surface of the white upper carboniferous quartzite 8.

Shal-Shal cliff.

The entire thickness from the base of the Spiti shales to the white quartzite I found to be, ignoring inches, exactly 3,920 feet, namely :—

Liassic and passage	26 feet.
Rhætic	2,197 ,,
Trias	1,570 ,,
Permian	127 ,,

The detailed section is in descending order as follows :—

		Thickness. Ft	In.
Lias.	1. Black shales and dark earthy limestone with oolitic structure containing:	13	0
	Belemnites bisulcatus Stol.		
	,, *tibeticus* ,,		
	,, *sp.*		

		Thickness. Ft.	In.
	Brought forward .	13	0
Lias—*contd.*	*Ammonites annulatus Sow var.*		
	,, *davesi* ,, ,,		
	Rhynchonella austriaca Suess.		
	Thalassites depressus Qu.		
	Ostrea sp.		
	Pecten sp.		
Passage bed.	85. Grey *Crinoid* limestone, very hard, weathering brown, thick bedded, with intercalated shales full of fossils. Containing a mixture of true rhætic and liassic forms . .	13	0
	Pecten bifrons Salt.		
	,, *mayeri Winkl. var.*		
	,, *lens Sow.*		
	,, *corneus Gldf. (non Sow)*		
	,, *cornatus Mun.*		
	,, *valoniensis Defr.*		
	Gervillia inflata Schfl.		
	Plagiostoma herrmanni Qu.		
	,, *giganteum Qu.*		
	Pholadomya ræmeri Ag.		
	Myophoria cardissoides Schl.		
	Cardium rhæticum Mer.		
	Terebratula horia Suess.		
	Rhynchonella fissicostata Suess.		
Rhaetic (Upper)	84. Grey *Lithodendron* limestone showing sections of small shells on weathered surfaces	6	0
	83. Grey limestone with fossils as in bed 85 with *Lithodendron* .	5	0
	82. Dark grey arenaceous *Crinoid* limestone with numerous white calcspar veins	9	6
	81. Uneven shaly beds similar to 82	3	0
	80. Dark grey *Crinoid* limestone alternating with shaly beds .	17	0
	79. Grey massive *Crinoid* limestone	17	0
	78 Calcareous sandstone, false-bedded, with shaly partings .	2	0
	77. Dark brecciated limestone with *Crinoids*	1	6
	76. Very hard grey *Crinoid* limestone with *Lithodendron* . .	5	6
	75. Flaggy beds of *Crinoid* limestone	2	3
	74. Brecciated bed, made up of angular pieces of dark limestone with a few rounded pebbles; thins out rapidly	0	8
	73. *Crinoid* limestone with some pebbles	3	0
	72. Dark *Crinoid* limestone in irregular beds with white calcspar veins	13	0
	71. Grey dolomitic limestone in beds of about 1½" alternating with papery shales	2	6
	70. Dark grey sandstone with *Crinoids* in thick banks, shaly towards base	16	0
	69. Dark grey flaggy limestone (unfossiliferous) in beds of about 2" to 5" with shaly partings	7	0
	Carried over	136	11

		Thickness. Ft.	In.
	Brought forward	136	11
68.	Brown shaly sandstone thinning out	0	5
67.	Flaggy limestone vertically jointed	9	3
66.	Uneven sandstone bed } with thin shaly partings.	0	6
65.	Grey calcareous sandstone } with thin shaly partings.	0	6
64.	Grey limestone } with thin shaly partings.	0	9
63.	Grey calcareous sandstone } with thin shaly partings.	0	6
62.	Grey limestone flags with shaly partings	2	0
61.	Grey friable shales	0	6
60	Grey limestone	0	9
59	Friable grey needle-shales	0	2
58.	Grey limestone in massive beds, with a few thin partings of shales	7	0
57.	Dark-grey needle-shales, thin out and pass into limestone laterally	1	2
56.	Thin flaggy limestone beds	0	6
55.	Dolomitic limestone	0	8
54.	Shaly limestone	2	4
53.	*Crinoid* limestone with some fossils of Koessen type	1	0
52.	Sandy shales	1	8
51.	*Crinoid* limestone	0	5
50.	Papery sandy shales	0	2
49.	Brown calcareous sandstone (fossils)	0	7
48	*Crinoid* limestone	0	4
47.	Shaly "	1	2
46	Shaly and papery calcareous beds	1	3
45	Grey limestone	0	3
44.	Sandy shales	0	3½
43	*Crinoid* limestone	1	0
42.	Papery calcareous shales	0	2½
41.	Sandstone shales	0	5
40	Shaly *Crinoid* limestone	0	8
39.	Flaggy *Crinoid* limestone with shaly partings	2	0
38.	Grey calcareous sandstone	0	4
37.	Shales	0	2
36.	Grey *Crinoid* limestone	0	7
35.	Sandy shales	0	5
34.	Papery marly shales	0	10
33.	Grey limestone with shaly parting	0	10½
32.	Friable calcareous shales	1	0
31.	Marly bed	0	8
30.	Irregular bed of grey limestone, thinning out	1	3
29.	Flaggy limestone with shales	6	9
28.	Grey *Crinoid* limestone with *Belemnites sp.*	0	5
27.	Limestone flags with friable shales	4	0
26.	*Crinoid* limestone with *Pecten bifrons Salt*	1	4
25.	Limestone flags and shales	2	4
	Carried over	196	3½

		Thickness. Ft.	In.
	Brought forward	196	3½
	24. Shaly calcareous sandstone	2	9
	23. *Crinoid* limestone with a shaly parting	1	9
	22. " " with *Pecten bifrons Salt*	3	0
Lower	21. Dark limestone alternating with shaly *Crinoid* beds	4	0
Rhætic.	20. Dark-grey limestone, dolomitic, with shaly partings	35	0
	19. Dark fossiliferous *Crinoid* limestone in massive beds	45	0
	18. Grey earthy limestone with numerous *Myacites sp*	7	0
	17. Hard limestone beds, containing many fossils, and on the weathered surfaces showing sections of large *Megalodon sp.*	35	0
	16. Hard *Crinoid* limestone in thick beds	7	6
	15. Dolomitic limestone	6	0
	14 " " in flaggy beds	3	6
	13. Massive grey dolomite, towards base rather flaggy	45	0
	12. Massive dolomite, with scarcely any bedding visible	135	0
	11. Massive beds of dark grey dolomite with partings of *Crinoid* limestone	223	0
	10 Dolomite in beds of about 4 feet thickness, reddish near base and containing *Lithodendron*	98	0
	9. Dark concretionary limestone changing laterally into cellular Rauchwacke, of reddish purple colour; in beds of 6 inches to 1 foot	5	0
	8. *Crinoid* limestone in thick beds	11	0
	7 Dark dolomites in massive beds, the contact surfaces knitted together, resembling sutures in the outcrop	100	0
	6. Dolomite and limestone beds, with "knitted" contact surfaces full of *Lithodendron* and with a few shaly partings	48	0
	5. Massive beds of dark blue limestone and dolomite alternating with flaggy beds of limestone; the latter form about 12 feet of the upper part of this sub-division; some of the beds contain masses of dark purple colour with *Crinoids*	50	0
	4. Dark dolomite beds with calcspar veins, thick bedded	147	0
	3. Same as 4, but beds are flaggy and have shaly sandstone partings	241	0
	2. Dark hard concretionary limestone, alternating with dolomitic beds	74	0
	1. Grey and reddish dolomites, forming perfectly inaccessible cliffs . . . about	700	0
	Total thickness of both lias and rhætic	2,223	9½

This continuous sequence of beds can only be roughly sub-divided into divisions; but although the beds all seem to pass gradually from one into the other it is not difficult to observe that great differences exist in lithological character of the strata which form this section, as indeed is the case in all the other rhætic localities in the Central Himá-

layas. It will be seen even from this description, at least three characteristic divisions may be distinguished below the uppermost limestones with liassic fossils. The lowest division which rests conformably on the upper trias is a great thickness of thick-bedded dolomites and limestones ; the middle portion of the cliff shows chiefly limestones, but they are thinner-bedded, show already shaly partings, and conspicuous on the weathered surfaces of the rock are large sections of a *Megalodon sp.* Above this division follow mostly thin-bedded *Crinoid* limestones with shales and sandstones, which is altogether a much more varied series of beds. *Lithodendron* occurs in all horizons, but is chiefly met with in the more massive limestone of the upper beds, and amongst them appear several horizons characterised by fossils typical of the Kœssen beds of the Alps

The whole sequence resembles strongly the rhætic formations of the Alps, both in lithological character and in the general distribution of fossil inclosures ; the following divisions might be compared with Alpine horizons :—

Numbers in the figured sections.		In the Alps.
15. Upper Rhætic.	3. *Lithodendron* limestones, interbedded with sandstones, *Crinoid* limestones, shales and containing several zones yielding Koessen types, beds 22 to 84.	Haupt-*Lithodendron* Kalk with Koessen beds.
14. Lower Rhætic.	2. Thick-bedded limestones, here and there dolomitic, with *Megalodon sp.*, beds 13 to 21	Dachstein Kalk.
	1. Great development of dolomites and limestones, beds 1 to 12.	Haupt-dolomite.

The beds which overlie this series conformably, some 26 feet in this section only, represent a very interesting horizon. The uppermost bed with fossils, there is no difficulty in identifying as lower lias. It is remarkable how very constant this horizon remains over wide areas. I have met with it along the whole extent of country from the Nepál frontier (Byans) to the Niti pass. Everywhere it contains some bed of dark shales with oolitic structure. The small thickness of beds, represented by sub-division 85 in this section, seems to form a passage from the true rhætic horizons with *Lithodendron* and Koessen fossils into the lias, with which I find it

most convenient to class it here. It contains fossils, amongst which rhætic types mingle with liassic, and conspicuous amongst them are the Starhemberg types, *Terebratula horia Sss* and *Rhynchonella fissicostata Sss.*

Trias of Shal-Shal.

As I have said already, this great sequence of rhætic and lias rests perfectly conformable on the upper trias, between which and the lower rhætic there is no very marked boundary. The system of beds below the above series is in descending order as follows :—

		Thickness Ft.	In.
Upper Trias.	144. Compact brown (liver-coloured) limestone; beds are nearly of equal thickness, about 12 inches, and are occasionally separated by greenish-grey shales. Numerous bivalves, closely allied to *Corbis mellingi Hau. var.*	152	0
	143. Liver-coloured brown limestone, alternating with greyish-green shales, containing— *Corbis mellingi Hau. var.* *Orthoceras sp.*	29	0
	142. Earthy limestone with shaly partings	228	0
	141. Shaly limestone alternating with earthy shales, containing *Spirifer lilangensis Stol. var.*	30	0
	140. Shaly limestone and shales with hard concretionary limestone	22	0
	139. Greenish-grey shales	4	6
	138. Limestone with chert nodules	1	6
	137. Flaggy limestone	5	0
	136. Friable greenish-grey shales, weathering brown, alternating with flaggy limestone	31	0
	135. Marly friable shales	5	0
	134. Hard grey limestone	4	0
	133. Hard grey limestone, weathering brown, rather silicious, containing concretions which yielded— *Opis globata Dtm.* *Acrochordiceras spinescens Hau.* *Tropites ehrlichi Hau. var. feistmanteli n. sp.* *Balatonites himalayanus Blfd.*		
	132. Grey earthy limestone beds, with marly and shaly partings, weathers brown	...	...
	131. Same as bed above, containing *Spirigera sp.* Total thickness of beds 131, 132 and 133	275	0
	130. Greyish-green micaceous shales with a few indistinct plant impressions	160	0
	129. Shaly grey earthy limestone	38	0
	Carried over	985	0

			Thickness. Ft.	In.
		Brought forward	985	0
	128.	Dark splintery limestone flags, with dolomitic beds, and very scarce partings of black shales	75	0
	127.	Black limestone beds of about 6 inches thickness each, which at intervals of about 3 feet are divided by about 3 feet thickness of black splintery shales containing—	152	0
		Halobia rarestriata Mojs. var.		
		Daonella tyrolensis Mojs. var.		
		„ *sp.*		
		and a species of the group of *Amaltheidæ.*		
	126.	Dolomitic limestones in more massive beds with a few shaly partings	38	0
	125.	Shaly limestone with—	38	0
		Daonella sp.		
		Spirifer lilangensis Stol. var.		
	124.	Thick-bedded shaly limestone with traces of fossils, mostly *Cephalopods*	48	0
	123.	Black limestone flags of about 12 inches thickness each, alternating with black splintery shales of about the same thickness	103	0
	122.	Very hard grey concretionary limestone in massive beds with subordinate partings of dark shales; containing many fossils very difficult to extract. About—	50	0
		Orthoceras dubium Hau.		
		Trachyceras voiti Opp.		
		„ *thuilleri Opp.*		
		„ *sp.*		
		Arcestes diffissus Hau.		
		Ptychites gerardi Blfd.		
		Pinacoceras floridum Wulf.		
		Pecten sp.		
		Myaconcha sp.		
		Pleurotoma sterilis Stol.		
		Reptilian bones (traces).		
	121.	Earthy grey limestone, shaly near base, yielding in large numbers—	3	0
		Rhynchonella semiplecta Mun. var.		
		„ *salteriana Stol.*		
Lower Trias.	120.	Hard grey splintery limestone	0	8
	119.	Dark friable clay shales, weathering in bright colours	0	3
	118.	Limestone, dark brown to black	0	4
	117.	Limestone with shaly partings	1	6
	116.	Limestone	0	1
	115.	Shales, friable, dark-grey to black	2	0
	114.	Limestone	0	7
	113.	Black shales alternating with 12 thin beds of limestone	1	0
		Carried over	1,499	5

	Thickness. Ft.	In.
Brought forward	1,499	5
112. Limestone	0	6
111. Black shales	0	4
110. Limestone	0	3½
109. Shales with thin limestone partings	1	2
108. Limestone	0	6
107. Shales, alternating with 11 thin limestone partings	2	0
106. Limestone	0	8
105. Shales	0	10
104. Limestone	0	6
103. Shales with 5 limestone partings	0	11
102. Limestone	0	5
101. Shales	0	7
100. Limestone	0	7½
99. Shales	0	6
98. Limestone	0	7
97. Shales and limestone partings	1	2
96 Limestone	0	8
95. Shales	0	7
94. Limestone	0	4
93. Shales	0	7
92. Limestone	0	9
91. Shales with 10 thin limestone partings	1	4
90. Limestone	0	7
89. Shales and limestone partings with *Norites planulatus Dekon.*	0	10
88. Limestone	0	6
87. Shales with limestone parting	0	1
86. Limestone	0	2
85. Shales with two limestone partings	0	8
84. Limestone	0	5
83. Shales	0	3
82. Limestone with one shaly parting	0	4
81. Shales with two limestone partings	0	6
80. Limestone, light-grey with *Monophyllites wetsoni Opp.*	0	3
79. Shales	0	5
78. Limestone	0	5
77. Limestone wi'h three shaly partings	0	6
76. Limestone dark, almost black	0	5
75. Limestone with 17 shaly partings	1	7
74. Shales	0	2
73. Limestone	0	6
72. Shales	0	½
71. Limestone	0	2
70. Shales with *Ophiceras tibeticum n.s.*	0	1½
Carried over	1,524	2

	Thickness. Ft.	In.
Brought forward	1,524	2
69. Limestone	0	½
68. Shales	0	2
67. Limestone	0	1
66. Shales	0	1
65. Limestone	0	1
64. Shales	0	1
63. Limestone	0	4
62. Shales	0	½
61. Limestone	0	1
60. Shales	0	2
59. Limestone	0	3
58. Limestone with 6 shaly partings .	0	6
57. Limestone	0	2
56. Shaly limestone	0	1½
55. Shales	0	1
54. Limestone with 2 shaly partings .	0	5
53. Limestone with shales . .	0	3
52. Limestone	0	5
51. Shales	0	½
50. Limestone	0	1
49. Shales and limestone . . .	0	2½
48. Shales	2	2½
47. Limestone	0	3
46. Shales	0	2
45. Limestone	0	2½
44. Shales	0	1
43. Limestone	0	3
42. Shales with a thin bed of limestone	0	5
41. Limestone with 9 shaly partings .	1	3
40. Limestone	0	1
39. Limestone	0	3
38. Limestone with 14 shaly partings	1	2
37. Limestone	0	2½
36. Shales	0	2
35. Limestone with shaly partings .	0	3½
34. Shales	0	1
33. Limestone with 3 shaly partings .	0	5
32. Shales	0	2
31. Limestone	0	2
30. Shales	0	3
29. Limestone	0	2½
28. Shales	0	2
27. Limestone	0	1½
26. Shales	0	1½
25. Limestone	0	1
24. Shales	0	1½
Carried over	1,536	9½

	Thickness. Ft.	In.
Brought forward	1,536	9½
23. Limestone	0	2
22. Shales	1	0
21. Limestone	0	3
20. Shales	0	1
19. Limestone	0	3
18. Shales	0	4
17. Limestone	0	3
16. Shales	0	10
15. Limestone with shaly partings	1	6
14. Limestone	0	6
13. Shales	1	0
12. Limestone	0	3½
11. Shales with layer of hard splintery limestone	0	4½
10. Limestone	0	3
9. Shales with a bed of limestone (1½) near top containing *Otoceras woodwardi n s*	5	0
8. Limestone	0	2
7. Shales	0	5½
6. Limestone with—	0	3
Xenodiscus gangeticus Dekon		
,, *buchianus* ,,		
5 Variegated papery shales	0	6
4. Limestone with—	0	4
Avicula venetiana Hau var.		
Myophoria ovata Br		
Posidonomya angusta Hau. var.		
Otoceras woodwardi n s		
Xenodiscus demissus Opp		
,, *gangeticus Dekon*		
3. Friable, papery shales with a parting of limestone (1") with—	0	0
Otoceras woodwardi n s.		
2 Dark grey limestone with shaly layers with—	0	5
Posidonomya angusta Hau var		
Gervillia mytiloides Schlot.		
Modiola triquetra Seeb.		
Myophoria ovata Gdfss.		
Avicula venetiana Hau.		
Bellerophon sp.		
Nautilus brahmanicus n.s		
Otoceras woodwardi n s.		
,, ,, *var. undulatum n s*		
Ptychites lawrencianus Dekon.		
Ophiceras medium n.s.		
,, *himalayense n.s.*		
,, *tibeticum n.s*		
,, *densitesta Waag var.*		
Carried over	1,551	9

		Thickness, Ft. In.
	Brought forward	1,551 9
	Xenodiscus gangeticus Dekon. " *buchianus* " " *demissus Opp.* *Trachyceras gibbosum n s.*	
Upper Permian Productus Shales (9).	1. Dark, carbonaceous, crumbling shales, micaceous, weathering in reddish and deep-brown tints, giving it a variegated appearance, with a few thin beds of hard grey limestone. The general character of these shales is very similar to the shales above, which yielded *Otoceras*, but are more carbonaceous and even contain some indistinct traces of plant remains, thickness	127
	They yielded— *Monotis sp.* *Productus latirostratus Howse var.* *Arcestes sp.*	
	Total thickness	1,678 9

The above series of beds rests on an eroded surface of the upper carboniferous quartzite (8) as already shown. It forms one continuous whole, each sub-division passing gradually into the next higher one. When I first visited the section I had failed to recognize the lowest bed (1), the black shales with *Productus* as being distinct from the lithological similar ones with *Otoceras*.

I regard them as permian, and the *Otoceras* beds above as a passage series from the permian into the lower trias, with which it is structurally closely connected in the Central Himálayas. The upper beds of this division must then be a representative of the lowest trias. The fauna contained in it, though some of the species remind one of similar forms found in the Alpine Buntsandstein (Werfen beds), has, on the whole, rather a permian character than triassic. With bed 121 we gain a distinctly triassic horizon, which yielded species allied to forms found in the Alpine lower trias. Above follow beds which represent the whole series of middle and upper trias, all of distinctly Alpine character. Even the very rock which has yielded fossils identical, or at least closely related to Alpine forms, resembles lithologically the equivalent Alpine horizon, and I was

naturally tempted[1] to give expression to this in my former paper on the Himálayan trias; this view, however, I find untenable.

We have therefore in the Shal-Shal cliff the following permo-trias section:—

Divisions.	Numbers in the figured sections.	Character of leading rocks.	Zones.
	13	Liver coloured limestones with greenish shales; earthy beds 135 to 144.	*Corbis mellingi Hau*
Upper Trias		Limestones; beds 129 to 134 .	*Tropites ehrlichi Hau.*
	12	Black limestones, dolomites and splintery black shales; beds 123 to 128.	*Daonella sp.*
		Hard grey limestone, bed 122 .	*Ptychites gerardi Blfd.*
		Earthy limestone; bed 121	*Rhynchonella semiplecta Mun var.*
Lower Trias and Passage Bed.	10	Black limestones and shales; beds 71 to 120	*Norites planulatus De-Kon.*
		Black limestone and shales; beds 2 to 70.	*Otoceras woodwardi n. s*
Upper Permian .		Black shales; bed .	*Productus sp.*

Profile plate 13 gives the view of the Shal-Shal cliff from the opposite, or western side of the valley, and it will be seen that the carboniferous white quartzite (8) below the trias section forms a precipitous cliff down to the river gorge. Some casts of *Brachiopods*, *Producti* and *Orthis* with *Corals* are common on the weathered

[1] Rec. Geol Surv. XIII, 91—113 (1880).

surface of the quartzite, but I could not get them out of the rock except in fragments.

North-east of Shal-Shal.

North-east of this section, about 1½ miles from the gorge of the Shal-Shal stream, a normal fault of very insignificant throw has brought down the Spiti shales to the level of the upper rhætic, from whence the section is repeated. From the top of this second cliff great sheets of the liassic beds dip 30° north-east below the jurassic Spiti shales, which contrast strongly with the underlying greyish-brown limestones. The Spiti shales form gently undulating grassy slopes, washed by numerous small streams and springs which rise in the ridge of the watershed some 3 to 4 miles north-east of Shal-Shal. These streams generally expose good sections of the jurassic shales, which yield the common Spiti fauna.

Cretaceous of the Balchdhura watershed.

The dividing ridge is capped by greenish-grey sandstones, and earthy beds of precisely similar lithological character as the cretaceous group seen near the Sirkia river in Húndés. They form steep cliffs along the whole watershed from east of the Silakank river to the Balchdhura pass, where they are seen to strike far towards the south-east. Their thickness cannot be less than from 1,200 to 1,500 feet. I found no fossils in the greenish sandstones, but was lucky enough to observe further to the south-east in the pass of Balchdhura a massive, almost crystalline white limestone overlying these sandstones conformably, which yielded many fossils which, although limited in species, yet prove the rock to be upper cretaceous (see chapter IV, p. 80); one may therefore assume that the greenish-grey sandstone represents the entire neocomian and lower cretaceous series. The Shal-Shal pass (16,390′) itself comes down to the level of the black Spiti shales. On each side the precipitous cliffs of the cretaceous group rise, and in profile show numerous minor flexures, although the beds finally dip below the highly altered *Nummulitic* strata of Húndés. Near Shal-Shal, as already shown, the cretaceous forms a shallow synclinal, and the beds dip about 20° inwards.

CHAPTER VI.—SECTIONS IN THE BHÓT MAHÁLS OF KUMAUN.

Johár sections. Physical difficulties.

The ground immediately south-east of the sections just described, belongs to the district of Johár, is mostly very difficult, and there are tracts within it which are practically inaccessible. I will at once state here that I have only been able to roughly reconnoitre the area of Johár, and had to connect my boundary lines on the map the best way I could by identifying the various rock-groups from afar off. That, however, is not such a risky undertaking as would appear to those who are strangers to Himálayan survey work. The hillsides are absolutely devoid of every scrap of vegetation in those heights, from 16,000 feet upwards. And where not obscured by snow or glacial debris, the principal rocks may with ease be determined from afar off. The bright red band of the upper haimantas (3), the duller red-brown of the red *Crinoid* limestone (7), and the dazzling white quartzite (8) above it serve as distinguishing landmarks which once fixed on the map enable one to put in the rest with fairly satisfactory accuracy.

Sections surveyed.

The points which I was able to examine closely were the following:—On the west side of the Johár palæozoic area, the neighbourhood of the Uja Tirche glacier; northwards the palæozoic rocks of the Kurguthidhar, where they join the Shal-Shal sections. In the eastern portion of this ground I touched the palæozoic rocks in the Girthi valley, following them near the boundary with the triassic system, and finally I crossed the entire palæozoic group from the Uttardhura pass to Milam.

Palæozoic rocks.

With the exception of a small triangular remnant of carboniferous rocks south of the Kiangur peak connected with the Uttardhura synclinal, the main ground of the palæozoic rocks of Johár forms a belt of from 7 to 8 miles wide and running due north-west to south-east.

The boundary with the permo-trias group runs in approximately the same direction, in a zig-zaging line from near the east slope of the Kurguthidhar to the Uttardhura pass. Near this boundary the upper carboniferous dips from 20° to 40° below the permo-trias, and within

the belt, the palæozoic group is generally less affected by folding than in the neighbouring mesozoic area. Roughly speaking, they from several way anticlinals, amongst which some portions stand out in the shape of low domes connected by anticlinals. This feature may be viewed from the upper Girthi valley.

Fig. 20. Kurguthidhar glacier, south-west of Rimkin Fa

These areas are, the mountain mass of the Kurguthidhar, the nameless peak (20,344′) east of the Uja Tirche glacier, and the mountain mass south-west of the Uttardhura Pass. These form, as it were, low domes or inverted cup-shaped bosses in the great palæozoic anticlinal. The same structure in also traceable in the adjoining permo-trias belt, as will be shown.

In the neighbourhood of the Uttardhura the palæozoic rocks form a synclinal enclosing triassic beds; I will describe this feature in detail further on.

The triangular shaped carboniferous ground south of the Kiangúr belongs to the north-east flank of the Uttardhura synclinal, though greatly disturbed by the south-eastern extension of the Painkanda fault, which may be traced so far.

The boundary between the silurian system and the haimantas I believe generally to be a faulted one in Johár. The only evidence I can bring forward to prove this are observations near the western and eastern limits of this ground. The fault near Malari (south-south-east of Niti) I believe to be connected with the crushed position of the older palæozoic rocks near the upper Uja Tirche glacier. Some five miles south of the Uttardhura pass I observed a fault, the general direction of which is south-east to north-west; it has lowered the carboniferous of the Shillong to the level of the haimanta system.

It is very probable that these three points all belong to one fault or system of faults, more or less parallel with the great Painkanda fault, and as such I have shown it in my map; it will be very difficult to collect further proofs in support of this assumption, as the whole, or nearly the whole, of the region between these points is situated at a height of over 20,000 feet sea-level, and in consequence is nearly everywhere completely hidden under perpetual snow.

Sections of the palæozoic group revealed that the silurians are composed of the same rock-series already described in the Niti sections. They are for the most part hard quartzites with greenish grey shales above and near the base of the system limestones, which have yielded lower silurian fossils.

The remarkable feature of the carboniferous system is that it seems to swell greatly in thickness as one advances towards the south-east. The lower portion, the dark blue concretionary limestone (6) is in great force. It forms the lower slopes of the nameless peak (20,344′) south-west of Girthi encamping ground, and I again traversed it between Milam and the Uttardhura pass. This formation is lithologically most characteristic, and though I have found no fossils in it in the Johár ground, its position between the silurian quartzites (5) on one hand, and the overlying carboniferous red *Crinoid* limestone (7) into which it passes gradually, defines its age as devonian, or lowest carboniferous.

The red *Crinoid* limestone (7) with the white quartzite (8), both nearly devoid of fossils, cap the great dome-shaped anticlinal of this nameless peak, the sides of which have been denuded down to the lower carboniferous. More or less parallel with the permo-trias boundary, strips of these two upper carboniferous divisions may be traced from the Kurguthidar to the Uttardhura.

In the profile pl. 10 the palæozoic group is seen on the left side of the valley dipping gently forwards north-east, and falling under an angle of from 40 to 60° below the trias on the right side of the Girthi valley. The latter has eroded through the entire group, and exposed the whole of the carboniferous rocks, and further down the stream, the silurian system also. On the right side of the valley rises a steep, generally inaccessible, cliff of trias and rhætic which faces south-west and exposes the same section as observed at Shal-Shal, and forms in fact a continuation of the same scarp (see pl. 10). The uppermost beds of the cliff are formed by the dark earthy shales which I believe to represent a liassic horizon. This with the *lithodendron* limestones below forms a high crest, eroded into wall and turret-shaped masses forming a dip slope to north-east and presenting a precipitous scarp to south-west. The entire mass of the trias-rhætic group dips to north-east,

Trias and rhætic.

but are greatly crushed and contorted into several inverted folds, amongst which some local faulting may be observed. The most conspicuous flexure runs between

Flexures of the Kiangur.

Fig. 21. Profile of the Kiangur pass.

Lapthal and the Kiangur pass (see sections in pl. 2), which incloses crushed Spiti shales in an inverted synclinal of rhætic and liassic beds. The feature is clearly seen on the naked hillsides near the Chidarmu encamping ground, and about four miles south of it in the Kiangur pass itself (see fig. 21). The structure is further complicated by extensive denudation, which in some cases has exposed the rhætic down to its lowest beds.

East of Chidamu Spiti shales and cretaceous.

East of this inverted flexure the bedding is normal, and the Liassic limestone and shales are seen to be overlaid by the black jurassic Spiti shales, which are again in turn followed by the cretaceous system (18 in the sections on pl. 2). The dip is from 25 to 30 due east near the Kiangur pass. The crest of the high range which forms the boundary with Tibet here, is formed by upper cretaceous white limestone with fossils. The peaks of the Kungribingri No. 2 are formed of this rock, which overlies the greyish-green lower cretaceous (18) conformably.

North-east of Lapthal.

A similar section is seen to the north-east of Lapthal. The undulating downs, which form the grazing district of Lapthal, are mostly within the belt of Spiti shales which here also rest conformably on the liassic strata. They have a rolling dip from 15 to 25° to the north and north-east, passing upwards into the greenish-grey cretaceous sandstones, shales and limestones of the Balchdhura. The boundary of the cretaceous system may be seen where the ground rises towards the north, in the neighbourhood of the Sangcha Talla and Sangcha Malla camping grounds. The ascent to the Balchdhura pass (17,590′) leads mostly over cretaceous rocks, which are here disturbed by igneous rocks. They are clearly intrusive; it is a basaltic trap, associated with serpentinous masses, and I believe forms part of the younger eruptive rocks which are largely represented in Eastern Húndés, and to which probably a middle tertiary age must be assigned. Some of the traps seen in the cretaceous might be contemporaneous, but during my short stay in the frontier district I have not been able to separate them from the undoubtedly intrusive ones.

Traps.

North-east of the Balchdhura pass the cretaceous rocks are overlaid by greatly altered strata with masses of igneous rock. I believe them to form part of the *Nummulitic* beds of Húndés which I observed north-west of this point. Beyond the rugged belt formed by this series, is seen the gently undulating plateau of Húndés, sloping about 3 to 5° towards the Sutlej. Judging from the horizontal stratification we have here the eastern continuation of the post-tertiaries of Dongpú which I have described above.

Nummulitic beds of the Balchdhura.

The south-eastern extremity of the permo-trias area of Johár forms one of the most instructive sections in this part of the Central Himálayas. The lateral pressure which the entire sedimentary belt has suffered resulted in a very complex flexure of the various rock systems composing them. In the Niti area, this pressure became partially relieved by a system of parallel faults, of which an extended and important one is the great Painkanda fault described already. Through it the younger beds have been pushed partly over the older section, and thus relieved the great lateral pressure and consequently left the sections on both sides of the fault to a great extent in normal order, which favoured the detailed examination of it. As I travelled to the south-eastwards it became apparent that the effect of the fault became less visible with each stage, and finally near the Uttardhura there are only some very slight dislocations observable, such as occur in every section in the Himálayas, and if they were not situated in the strike of the great Painkanda fault might pass unrecorded on the map. But the great pressure had to result in some change in the sedimentary rocks, and here it has taken the form of extensive folding. This feature begins to show itself clearly east of the Silakank and Marchauk ridge, and increases in importance to the south-east. The flexures grow gradually steeper till east of Girthi they become inverted and most complicated. Further on it will be shown that this system of parallel folding and inversion becomes still more complicated, and it seems to extend far towards the easternmost margin of my ground. There faults disappear almost entirely, or are

Synclinal of Uttardhura pass.

Fig. 22. Profile of the Utardhura pass

of very minor importance in the structure of the mountain ranges. Again, it may be observed that also here the more yielding strata, shales and thinner bedded limestones have suffered most, and they are frequently crushed into the most complicated plications within synclinals formed of more rigid rocks, which become locally faulted, whilst the softer rocks adjoining have been crushed to conform to the change in the lateral distribution of rock formations.

Such a flexure is the synclinal of the Uttardhura pass (fig. 22 and section 3 in pl. 2). One of the branches of the Bamlás glacier descending from the high peaks (19,340′) south of the Kungribingri has traversed the synclinal at right angles to its strike and exposed a profile which I give in the view fig. 22 South-west of Bamlás the palæozoic group forms a low anticlinal, the carboniferous white quartzite (8) being seen to dip about 40° below the *Productus* shales (9). A small fault half a mile from Bamlás camping ground (15,320′) repeats the section (see pl. 2), but the throw is insignificant. North-east of the pass the white quartzite (8) is again cropping out from below the *Productus* shales (9), dipping about 45° to 50° to south-west. Nearly the entire synclinal is exposed by the branch of the Bamlás glacier south of the Uttardhura pass. The *Productus* shales are overlaid by the lower trias (10) up to and including some remains of the beds with *Ptychites gerardi* (Muschelkalk) which are pushed over the rigid quartzite (8) folded and twisted in the most complex forms within the synclinal. The soft yielding carbonaceous *Productus* shales acted, as it were, as a lubricant between the massive quartzite below and the partially rigid lower trias limestones, which were consequently folded and twisted quite independent of the underlying stratum of quartzite.

Continuity with the Lissar valley flexures.

The flexure extends far to the south-east and forms no doubt part of the narrow synclinal of the upper Lissar, which I shall describe further on.

Between the Uttardhura and Milam.

Between the Uttardhura and the village of Milam the road passes over the entire sequence of palæozoic beds, but they are greatly obscured by the recent and sub-recent gravels, and the cones of *debris* on each side of the valley of the Gori Ganga. The beds have all a steady north and north-east

dip south of Shillong camping ground, where the boundary between the silurian and upper haimantas is indicated by the red quartz shales (3). South of it one passes in succession over the various quartzites, purple beds, conglomerates and greenish phyllitic slates of the haimanta system. This system seems to swell out in thickness considerably, and there is a gradual passage downwards into the rocks of the vaikritas. South of Milam a garnetiferous mica-schist is *in situ*, but the passage between it and the overlying haimantas is so gradual that a boundary line can only be drawn diagramatically. The mineralogical character of the shales and quartzites lying below the typical purple quartzites (2) with the boulder bed (conglomerate), and the adjoining metamorphic schists (vaikritas), are merging one into the other. The lowest haimantas also contain garnets and mica, the latter in the planes of bedding and irregular layers and crystals (in the plane of bedding) of felspar become frequent high up the series. Beds of granite (albite) intrusions, and syenitic granite, are found all throughout the lower haimanta system, their veins and complicated intrusions shewing distinctly in the darker coloured rock. South of Milam village one enters into the region of the great central flexure of gneissose rocks with the overlying older metamorphic schists.

Gradual passage between haimantas and the vaikrita system.

EASTERN JOHAR AND DHARMA.

What I said about the indistinct boundary of the vaikritas with the haimantas in the Milam sections may be applied also to the ground lying south-east of it as far as the Nepal frontier. I could actually follow the boundary only in two sections in this far extended area, namely, in Eastern Johár between the village of Chail on the Dharma (Dhauli) Ganga, and the junction of the latter with the Lissar river, where the haimanta rocks are overlaid by the silurian system, and in Byáns, along the section exposed by the Kali river. The actual boundary of the haimanta system near its base is so obscure, and the passage from the meta-

Haimanta boundary.

morphic rocks of the vaikritas into it so gradual, that it would be next to impossible to map exactly where one system begins and the other ends. In addition to this difficulty there is a purely physical one; as the junction of the two systems lies mostly in stupendous elevations, it is either generally obscured by masses of snow and glaciers, or else by enormous cones of *debris* shot out by the numerous glacier-filled ravines. The boundary line in the Dharma area is therefore more or less diagramatic; it is based on two actual sections, in some places on observations made at considerable distances with the aid of a telescope, and for the rest on conjecture. The upper boundary, however, has been actually observed, and is generally as accurate as such boundary lines can be The upper limit of the haimanta system is definitely determined by an almost uniform belt of bright-red and light-green quartz shales (3); they are the same as observed in the Niti and Milam sections, and they form everywhere the base of the lower silurian system. The belt of the haimantas is roughly speaking from four to six miles broad, and I followed it from the Milam valley in a south-easterly direction as far as the Nepál frontier, a distance of over fifty miles. Within this belt it includes some of the highest points of the Central Himálayas and numerous heights of over 20,000 feet between which many of the largest glaciers of this part of the Himálayas rise.

Thickness.

I found the strike of the strata composing the system of nearly uniform north-west to south-east direction but with very varying dip. Without making very close studies of the various divisions of the system, it would be impossible to arrive at a correct estimate of its thickness, as within the belt, fold on fold, with many minor dislocations may be seen which all more or less have the same general strike of the belt. But I do not think that on the whole I would be justified in believing the haimantas of this area to be of very much greater thickness than the same system is in the Niti or Bisahir sections. Some of the lowest semi-metamorphic beds are certainly wanting in the Niti sections, and if I estimate the thickness of the haimantas of the latter as 4,000 feet

I believe it will be found that the thickness of this system in the Dharma area will be found to be below 6,000 feet.

The lower boundary is, as I have already remarked, very obscure.

Beds at base. Granite.

The vaikritas on which the system rests consist of metamorphic schists, micaceous with garnet as accessory mineral and even gneissic schists with 'greisen' is common. Besides this, along the entire fifty miles of this boundary, hornblendic granite occurs as intrusive rock, and to its presence the local metamorphic character of the lowest haimantas may be ascribed.

Between Séla and Tuktung.

In the section formed by the Dharma (Dhauli) Ganga, I observed a high anticlinal south of Séla formed of gneiss in massive beds, which I could not distinguish in the field from the gneiss which forms the central range of the Himálayas. South of it, it is followed by a succession of anticlinals with deep synclinals separating them. The dip of the northern flank of the Séla anticlinal averages about 40 N.E. to N.

Granite, in intrusive form, is frequent and not only forms massive bosses but traverses the gneiss in all directions in the form of veins. It becomes more conspicuous nearer the boundary of the haimantas, where near Nangling and Chail it is seen to enter a quartzose schist, which I assume to belong to the latter system. Between Báling and Tuktung on the Dhauli Ganga, the rocks are semi-metamorphic, *i.e.*, it is a succession of quartzitic beds, with micaceous and calcareous stages, containing garnet, and quartzite conglomerate. The whole system is much contorted and faulted (see fig. 10) with dips varying from 30 to 50° N.E. to N.E. by N. This lower series seems to represent the lower haimantas seen north of Milam, which rest on the crystalline (vaikrita) schists of the north slope of the Nanda Devi. It is impossible to separate it from the upper haimantas, as the passage is perfectly gradual. Hornblendic granite traverses the lower haimantas in all directions as veins and intrusive masses, which is especially well seen near Tuktung (fig. 9), where the granite forms a perfect net work of veins in the quartzose schist on the right side of the valley.

Near junction of Dhauli and Lissar.

Between Goa and the junction of the Dhauli and Lissar rivers the haimantas assume their normal aspect. They are chiefly composed of quartzite of dark-grey to purple colour, associated with great thicknesses of quartz-shales and beds of purple quartz conglomerate. The latter differs in no wise from the conglomerate of the Niti sections. It consists chiefly of rounded boulders of quartz rock, with gneissic pebbles intermixed, all cemented together with the same purple quartzite forming the adjoining stages of the system It also has been traversed by granite veins. The purple quartzite, with its associated beds of conglomerate, is well seen between Goa and Dákar, where it is traversed by granite veins, often at right angles to the bedding of the haimantas.

Plications near Baling.

How impossible it is to form an accurate estimate of the thickness of this system may be understood when viewing the complicated folding and plication of the schists forming the lower series of the haimantas near Báling on the Dhauli Ganga rendered in fig. 10, p. 44. This plication in connection with the repeated greater flexures make the thickness appear to be much greater than it actually is, and I think that 6,000′ will be found to be the very utmost limit which it is possible to assign to the system.

Kali river sections.

The section exposed by the Kali river near the eastern limits of my survey reveals a similar succession of strata within the haimanta system. The lower boundary with the vaikritas may be fixed about 1½ mile south-west of Garbyáng, and is there as undefined as near Chail. The rock, which forms the base of the system, is a massive gneiss associated with a hornblendic granite, and showing numerous intrusions of the latter which not only have affected the gneiss below but also the overlying haimantas. The lower series of this system which overlies the vaikritas is mainly formed by quartz-shales, with true mica schist and quartzites, and followed higher up by what I may term the upper haimantas, consisting of purple quartzites, pink or purple conglomerate, shales and calcareous beds. The belt is much jointed and traversed by

faults which run parallel to the strike of the beds. The dip of course is very variable. South of the Nampa river (Nepál) it is due east; south of Tinkar (Nepál) it is north-east, which is the average direction of the dip in the area further west. North of Kaua Malla (Kali river valley), the quartzites are seen to dip 90° north-east by north, and north below the red quartz shales which mark the boundary with the silurian. The dip decreases further north-west in the valley of the Kuti Yangti, where it averages about 50° near the boundary with the silurian.

Boundary with the silurians

The boundary with the silurian system is fortunately quite clear. The haimanta quartzites are seen to pass upwards into light greenish-grey quartz-shales, which themselves are of very little thickness, and pass again into bright pink or red quartz-shales, which show cleavage in a remarkable degree in some localities, amongst others south of the Ráma encamping ground This series of shales is only some 200 to 500 feet in thickness, but it seems to be quite constant and may be said to mark the boundary with the silurian. It is overlaid by lower silurian beds with fossils.

Red quartz-shales (3).

This distinguishing band of red quartz shales runs from near Shillong Talla (north of Milam) in a south-westerly direction, and I met it again at the north slope of the Bambadhura peak (20,760′) immediately below the highest point. From there it meanders along the north-east slope of the high range, conforming more or less to the present contour of the ground, runs across the trough of the Chingchingmauri glacier, descends into the valley of the Lissar above Sepi, through the Dhauli valley to the Ráma glacier, from where the strike is nearly due east as far as the Kuti Yangti. From thence it is seen to skirt the left side of the valley to a point in the Kali river valley, some 2 miles above the junction of that river with the Kuti Yangti, and after that it skirts the immense spurs of the Nampa peak in Nepál.

Inverted synclinals of palæozoic group.

Excepting in the Upper Lissar valley, the dip is normal below the silurians, but between the Chingchingmauri and Bampadhura heights the position is inverted

(see secs. 1, 2, 3 in pl. 7 and pl. 8.). The palæozoic group forms there an enormous synclinal, inverted and leaning over to north-east.

In some sections (secs. 1 and 2, pl. 7.) there is enough left of the old flexure to show the original position, whilst in other sections (sec. 3 for instance) subsequent denudation has removed the top of the anticlinal west of the palæozoic synclinal, and thus the haimantas are in inverted position over silurian beds.

It is quite likely that remains of silurian and even later palæozoic beds may be found within the many folds of the haimantas in the belt just described; but in an area so encumbered by masses of debris and glaciers, to map correctly each outlying patch of silurians would have required a longer time than I could devote to the work.

The silurian, carboniferous and mesozoic systems of Eastern Johár and Byáns.

Complicated system of flexure.

The feature which seems most remarkable in the geological map of this part of Kumaun is the apparent complication in the distribution of the various rocks. The different systems form narrow and long strips of irregular outline, which run more or less parallel with the strike of the sedimentary belt of rocks. In fact the latter is formed by about eight synclinals with corresponding anticlinals separating them. The most western, those of the Lissar and Dhauli (Dharma) Gangas are continuations of the flexures of Western Johár, as for instance those of the Uttardhura and Kiangur passes. The more eastern flexures, those of the Kuti Yangti and of Byáns, may probably be continued into Húndés, where they are covered by the younger tertiaries.

A look at the map will show that by far the greater portion of the ground is covered by palæozoic rocks, and that the mesozoic group is confined to comparatively narrow strips within the synclinals.

The mapping of the various rock-series would have presented immense difficulties in such a disturbed area, were it not for several very easily recognized beds, which, as in the Niti sections, helped to explain the stratigraphy. Especially it was the trias with the underlying black *Productus* shales (9) which are unmistakeable and which

helped to explain the very intricate structure of the folds of which they usually form the innermost strata.

The sections of the Lissar Valley and (Dhauli) Dharma Ganga.

The Lissar river runs along the top of an anticlinal during the upper half of its course, and the same may be said of the valley of the Dhauli (Dharma) Ganga further east, as may be seen in the various sections of plates 7 and 8.

Bambadhura sections.

The section which shows the complexity of the flexures best is the one exposed between the east slope of the Bambadhura heights and the Dhauli Ganga, section 2 of plate 7. Here the acute angle formed by the inverted unsymmetrical flexure of the palæozoic group is well exposed in the ridge which separates the two Bambadhura glaciers, a feature which will be recognized in the profile plate 14. Beyond the figured section the quartzites and shales of the haimantas form a high anticlinal, and the range, of which the Bambadhura peaks are prominent heights. North-east of this range the palæozoic group forms an inverted, unsymmetrical flexure, whose upper flank is seen to run along the south side of the range which separates the two Bambadhura glaciers. About half-way up the southern of the two glaciers the flexure bends sharp round to a south-west dip, forming a deep synclinal, north-east of which follows the anticlinal of the Lissar river.

The bright red quartz shales (3) and the white quartzite (8), again help to fix the limits of the silurian and carboniferous systems. The red quartz shales (3) are without a trace of fossils throughout, and is overlaid by a thickness of about 1,500 to 2,000 feet of silurians, characterized by the prevalence of dark limestone beds near the base of the system, and quartzites which form the more important upper half of it.

This system, even without the fossil remains which are common throughout its thickness, is easily recognized as silurian, and it is also here conformably overlaid by the dark-blue limestone (6) in which I have found no fossils in this section, but which I consider to be of devonian age. This dark corcretionary limestone is followed by

some 1,500 feet of limestones, occasionally flaggy, which pass gradually from the dark limestone below and are characterized by fragments of *Crinoids.* I distinguish this division in the sections by 7 and 7a. The upper part of these limestones change from the dull blue-grey colour of the inferior beds into a brownish-red, and brick-coloured earthy limestone, which also yields *Crinoid* remains. Near its upper limit quartzitic strata are seen to alternate with it, and the series is followed finally by at least 2,000 feet of the white quartzite (8) of the upper carboniferous system. The uppermost beds are here seen in thinner beds than I have hitherto observed and in character approach a quartz sandstone, whilst the lower beds which make up the bulk of the division are nearly all massive, almost unstratified white quartzite. The latter forms wide areas in all the Eastern Johár and Byáns districts and is prominent in most of the sections. The deep synclinal on the right side of the Lissar Valley is nearly entirely formed of it. The high conical peak in the range between the two Bambadhura glaciers (see plate 14) is formed of series 5, 6, 7, and crowned by a cap of white quartzite (8), the remains left by the denudation of the upper and longer shoulder of the anticlinal flexure.

Two miles north of the section (3 of plate 7) exposed along a narrow ridge separating two glaciers, a similar structure may be observed, with this difference, that the synclinal formed by the white quartzite (8), is much narrower, though well defined by the inclosed *Productus* shales (9), and the passage beds of the *Otoceras* zone (10). Of the palæozoic group only the lower side of the great inverted anticlinal is seen, the upper side, which is preserved in the Bambadhura section (2 of plate 7) having been denuded, and so left what appears simply an inverted series of the palæozoics with south-westerly dip.

A middle stage of denudation is seen in section 1, plate 7, in the valley of the Jokneking glacier. Here the reversed flexure embracing the palæozoic group has been partially preserved, whilst remains only of the upper side of the fold show the true stratigraphical relations of the beds forming it.

The carboniferous system (7, 7a, and 8) forms a strip of more or

less considerable width from near the head waters of the Lissar river and extending far to the south-east. The Lissar river flows, during the greater part of its upper course, along the axis of a symmetrical anticlinal formed of carboniferous rocks, leaving it near the end of the Chingchingmauri glacier, where it traverses the lower palæozoics in its southward course. This strip of upper carboniferous rocks is of great structural interest. The centre of it is formed by a symmetrical anticlinal (see all sections in plate 7) chiefly of the white quartzite (8). Along some miles of its course the river has eroded through this division down to the earthy brown-red *Crinoid* limestone (7a), as for instance, north-east of the Bambadhura (sections 2 and 3, plate 7). This anticlinal is flanked on both sides by a system of other plications, more complicated on the left (north-east) side of the valley than on the right, where I could follow with ease the reversed synclinal directed towards north-east, shown in the four sections of plate 7, and in the view, pl. 14.

Flexures of left side of the Lissar Valley.

The left side of the Lissar Valley shows a more irregular system of plications of carboniferous rocks, which form the broad range dividing the Lissar from the Dhauli Ganga.

The white quartzite (8) itself is of precisely the same lithological character, which distinguishes this rock in the more north-western tracts of the Bhót mahals of Kumaun. For the main part it is a thick-bedded sugar-grained pure white quartzite which below alternates with the Red *Crinoid* limestone near the boundary with the latter division, whilst in *some few* sections in the upper Lissar valley, some sandstone beds, of a dirty white colour, appear near its upper limit. Fossils are very seldom seen, and are generally casts only of *Orthis* sp., *Productus* sp., etc., but they appear only on the weathered surfaces of the more massive beds.

The high range which forms the left side of the Lissar valley presents a steep, in many places, inaccessible scarp of this white quartzite, at the base of which here and there the red *Crinoid* limestone (7, a), and the dark blue-grey limestone with *Crinoids* and *Producti* may be observed below the mass of debris and fans, which form the

undercliff. Were it not for the densely black *Productus* shales, which are inclosed in some of the deeper synclinals, and which show like a black band in the white quartzite cliffs, along both sides of the valley, one might easily imagine the latter to be an unbroken thickness of some thousands of feet, as the plications are squeezed into such limited compass in places, that the whole forms, as it were, one series, with perfectly isoclinal dip, the bends of the anticlinals having been denuded away.

This, for instance, is the case opposite the Jokneking glacier, and is a feature repeatedly met with in the sections of the Kuti Yangti. Guided even by the black *Productus* shales which are seen on the left side of the valley a mile or two higher up, I would not have felt quite satisfied about their not after all alternating with the white quartzite, if the synclinal, gradually widening and deepening, had not contained inclosed within the *Productus* shales the beds of the lowest trias with fossils.

Synclinals of the Lissar valley.

The right side of the Upper Lissar afford most interesting instances of such synclinals. The first indications of the black *Productus* shales, and some beds belonging to the higher *Otoceras* stage, are seen in the white quartzite cliff which forms the eastern termination of the range which divides the two Bambadhura glaciers, though the traces are too insignificant to map them.

The next spur which descends into the Lissar valley from the right side, some two miles from the former outcrop of *Productus* shales, shows a most instructive section (3 in pls. 7, pls. 14 and 15). Here, within a narrow reversed synclinal fold, lie highly contorted and crushed *Productus* shales, with overlying *Otoceras* beds. Of the latter the entire series seems preserved within the flexure, and as in most other sections of it, here also the soft *Productus* shales have acted as a sort of lubricator between the rigid white quartzite and the thin-bedded limestone beds of the *Otoceras* stage, and have permitted the latter to be crushed into numerous complicated folds, the *Productus* shales yielding and conforming to all the disturbance of the higher beds. The glacier which descends from the north slope of

the Bambadhura peak (20,760′), has cut through the beds at right angles to their strike, and so produced an unrivalled profile, which I was able to photograph from a short distance off (pl. 15).

Advancing still higher up the valley to near the sources of the river, I found that the synclinal just described gradually opens out, and in consequence the belt of *Productus* shales and lower trias widens considerably. The flexure becomes a nearly symmetrical one, and again a friendly glacier, descending from the enormous snow-covered heights from the water-shed between the Lissar and Tibet, has eroded through the flexures at right angles to their strike, and so exposed the grand section which I photographed in pl. 16[1] (see also sect. 4, pl. 7.). White quartzite is seen to form a trough in which lie the highly crumpled strata of the black *Productus* shales (9), and the dark limestone and shales of the *Otoceras* stage (10) of the lower trias, followed by grey limestone (11) belonging to the *Ptychites gerardi* stage of (Muschelkalk) the north-western sections. Higher up this glacier valley, the dark limestone (6) and below it the silurian system, consisting of flesh-coloured quartzites (5) greenish shales and *Coral* limestone (4), is seen to dip below the carboniferous system (7a, and 8). The silurians are shown in the photograph (pl. 16) in perspective.

Synclinal of water-shed between Lissar and Dhauli.

I have already given an outline of the structure of the mountain range which forms the water-shed between the Lissar and the Dhauli Ganga. It forms a great synclinal flexure with minor plications flanking and accompanying it.

The rock which forms the trough of this synclinal is again the white quartzite (8), in which the *Productus* shales (9) and the entire trias, rhætic, lias and jurassic Spiti shales are inclosed.

As much as has been left by the denuding agencies of streams and glaciers, the *Productus* shales and the mesozoic group form a strip from two to four miles in width, which thins out to a few yards only towards south-east. As has been indicated in the sections on pls. 7 and 8, this synclinal has in places been crushed and twisted

[1] See frontispiece in Suess, Das Antlitz der Erde.

W. Quartzite.

Trias and rhætic.

Spiti shales.

Trias and rhætic.

W. Quartzite.

Fig. 2

orth-w

into the most complicated folds. Everywhere the white quartzite (8) seems to underlie the *Productus* shales (9) conformably, though the contrast between the two rocks is as glaring as seen in the former sections.

Amongst the many sections across this mesozoic belt which I examined, perhaps one of the most instructive is the one (4, in pl. 7) which passes across the range in a south-west to north-east direction near the sources of both the Lissar and Dhauli rivers. As already shown, the white quartzite (8) forms two enormous synclinals, dipping under a high angle below the younger rocks; on an average about 60° north-east in the Lissar valley, and from 80 to 90° south-west in the range which forms the water-shed between the Dhauli Ganga and the provinces of Húndés of Tibet. Within these deep synclinals, see fig. 23, I found crushed *Productus* shales, the whole triassic system, rhætic, lias and a remnant of the black Spiti shales. It is a rugged and for the most part snow-covered ground and most difficult to work over, and were it not that most divisions have yielded characteristic fossils, it would have been almost impossible to unravel the section.

Crossing this watershed (several of the peaks in it are over 20,000 feet sea-level), from south-west to north-east, I traversed a complete synclinal of the mesozoic group. Near the centre of it Spiti shales very much crushed are inclosed within the lias and rhætic, and from there to north-east the following section is seen in descending order:—

Mesozoic section of the Lissar-Dhauli water-shed.

Systems.		Number in sections.	Description of strata.
JURASSIC		17	Black Spiti shales, very much crushed; they contain nodules with jurassic *Ammonites*, exceedingly difficult to get out of the rock, which crumbles away.
LIAS		16	*Crinoid* limestone with fossils.
RHÆTIC	Upper	15	Limestone with *Lithodendron* and many small *Bivalves*.
	Lower	14	Massive hard grey dolomite and limestone.

Systems		Number in sections.	Description of strata
		13	Shales and limestone in great thickness, but no fossils found.
	Upper	12	Hard black splintery limestone, and shales with numerous white calcspar veins traversing the series in all directions; contains: *Daonella sp.* and Hallstadt types of *Cephalopods*. The thickness of this division is very considerable, but I could not measure it.
TRIAS		11	Hard grey limestone, with traces of *Cephalopods*, thickness about 100 feet.
	Lower		*Otoceras* stage; lithologically similar to the lowest trias (passage) beds of Shal-Shal; yielded chiefly *Cephalopods; Xenodiscus demissus, X. buchianus, etc.*; about 200 feet.
PERMIAN			*Productus* shales; they are here rather thicker than in the Painkanda sections, and may roughly be estimated at 250 feet. They are quite black, carbonaceous, crumbling clay shales with partings of ferruginous concretionary layers and nodules of clay iron ore. Fossils are scarce and not well preserved, but *Productus semi-reticulatus* may be identified amongst them. Carbonized impressions of vegetable origin and very indistinct remains of stalks.

Resting on: white carboniferous quartzite (8).

Continuation of Kiangur section.

This section (4, pl. 7) seems to be the south-eastern continuation of the sections exposed between the Uttardhura and Kiangur passes north of Milam. Not only does the Lissar and Dhauli area lie within the strike of the flexures north of Milam, but the general structure of the two synclinals correspond in a remarkable degree. The synclinals of the Kiangur fig. 21 and Chidamu (pl. 2), should be compared with the upper Dhauli Ganga flexure (4, pl. 7), and the conspicuous likeness of the Uttardhura (pl. 2 and fig. 22) structure will be recognised again in the upper Lissar river synclinal (4, pl. 7 and pl. 16). Unfortunately I have not been able to examine the intervening ground, owing to the obstinate and often forcible obstruction of the Tibetan petty officials who keep guard over the passes leading into Húndés.

Section 3, pl. 7.

Following the range or ranges, which forms the watershed between the Lissar and Dhauli Ganga still further down to south-east, the structure becomes rather

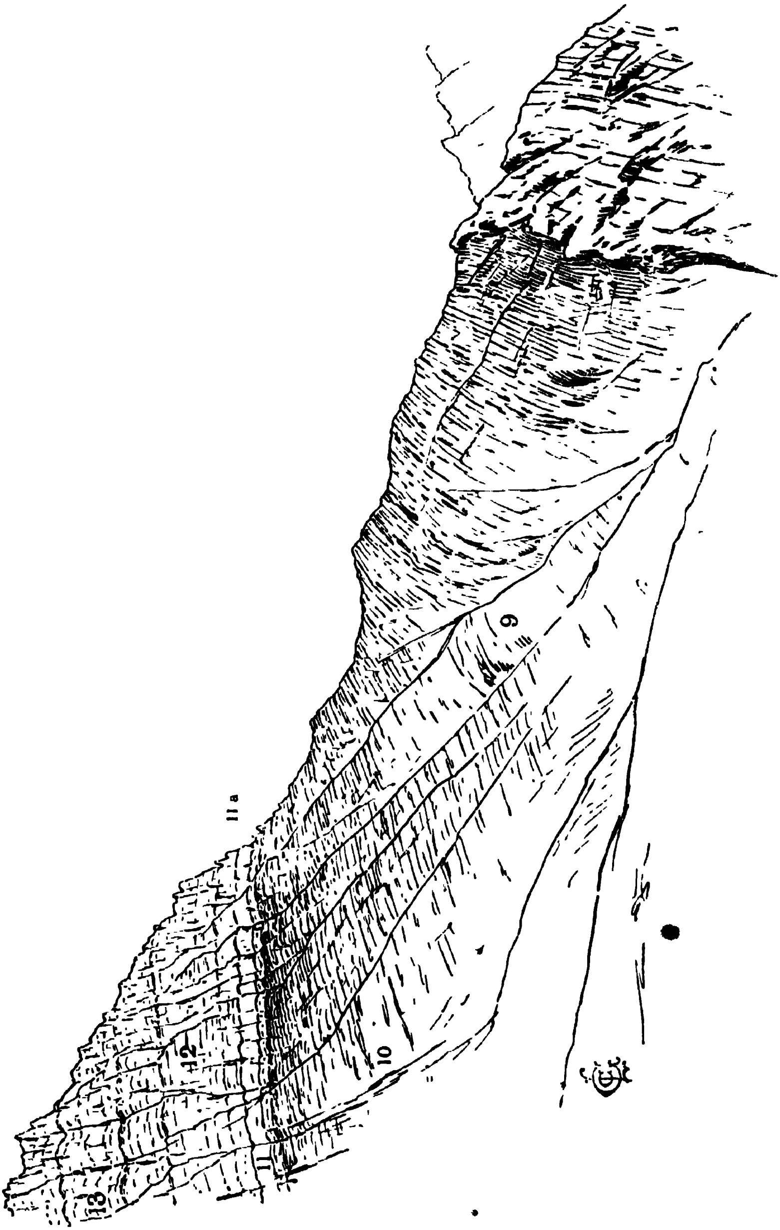

Fig. 24 Cliff opposite the Bambadhura glacier, left side of the Lissar valley.

more complicated. The river has scooped out the carboniferous down to the lowest beds of this system which has been laid into one or more folds, in one of which (3, pl. 7) some remnant of the *Productus* shales is left. The situation is east of north-east, opposite the synclinal already described above (see pl. 15).

The range forms a steep but not inaccessible cliff, and where not obstructed by the enormous undercliff of debris, exposes a very clear section (fig. 24). It forms an ascending section to about two-thirds of its height, where it passes through the axis of a reversed anticlinal and becomes rather more confused, till one reaches the synclinal trough, and the south-eastern continuation of the permo-trias section above described. From the strip of *Productus* shales (9) through the white quartzite (8), and the underlying red *Crinoid* limestone (7, a) the section is fairly good and I found in descending order:—

Systems.	Numbers in section, pl. 7.	Description of strata.
LOWER TRIAS		Remains of limestone beds, much crushed, but yielding fragments of fossils of *Otoceras* stage.
PERMIAN .		Black shales with *Productus semi-reticulatus*.
		f. White quartzite in thin beds, about 50 feet.
UPPER CARBONIFEROUS.		*e*. White quartzite, with calcareous sandstone partings and some irregular inclosures of earthy shales, which weather brown; about 30 feet.
		d. White quartzite in massive beds, with scarcely any bedding visible. About 300 feet.
		c. Dark red *Crinoid* limestone with dark crumbling shales.
	7 a	*b* Grey earthy limestone with red *Crinoid* limestone beds; b and c together about 400 feet
LOWER CARBONIFEROUS.		*a*. Bright light bluish grey earthy limestone with *Crinoids*.
	7	Obscured by the undercliff.
		⋮
		Bluish grey limestone.

Climbing up the range, and over the eroded and rugged bend of the reversed anticlinal of upper carboniferous (8), I reached again a tolerably complete and more or less normal section of permo-trias, which forms the highest part of the range. I found it quite impossible to arrive at even an approximately correct estimate of the thickness of its divisions, as the top of the range is broken up into endless jagged ridges, mostly formed by the highly inclined beds which form the upper trias and rhætic, and as they are often quite inaccessible one has to skirt them by climbing over the numerous small glaciers and moraine matter which fill in the unevenness of the ground. The highest crags and the centre beds of the synclinal are generally formed by the lower rhætic, which is flanked on each side by a descending section of triassic rocks, which again rest on permian *Productus* shales. These centre beds are mostly massive, dark-bluish grey dolomites and limestones, which may be identified with the lower rhætic. Fossils I have found none in them.

West slope of section 3, pl. 7.

Below this series I found in *descending* order on the west slopes of the range the following section (3, pl. 7).

		feet	inch.
UPPER TRIAS	13. Flaggy limestone-beds with shales, great thickness, passing downwards into		
	12. Black splintery limestone and shales, some 500 to 700 feet thickness; *Daonella* and fragments of Hallstadt fossils.		
LOWER TRIAS	11. About 80 to 100 feet of massive limestone of light grey colour.		
	10. Dark limestone in thin beds with dark shales alternating; fossils of the *Otoceras* stage.		
PRODUCTUS SHALES. (9)	*i*. Black crumbling shales, with ferruginous concretions in irregular partings, thickness	85	0
	h. Micaceous and calcareous sandstone with *fucoid* markings; with shaly partings and irregular thickness about . . .	2	0
	g. Micaceous dark shales, which weather in bright colours, with ferruginous concretions. Shales show *fucoid* markings .	7	0
	f. Same as (h); with *Brachiopods* . . .	3	0
	e. Same (*g*)	51	0

		feet	inch.
	d. Dark limestone with indistinct *plant* remains	0	8
PRODUCTUS SHALES—*contd.*	Dark micaceous shales with *fucoid* impressions	26	0
	b. Argillaceous limestone in thicker beds .	8	0
	a Earthy shales with *fucoid* impressions .	5	0
UPPER CARBONIFEROUS (8) .	White quartzite series as above described.		

Near the base of this section the dip averages 22 to 25° to north-east, but it rapidly increases near the centre of the synclinal, where the beds are raised up vertical before turning over to the opposite direction, south-west, east of the axis of the range. On the Dhárma side of the range I descended over the upturned edges of the beds; the general succession is as seen on the west side of the range, and the lowest beds seen belong to the upper trias (13 and 12), which are exposed by the Dhauli Ganga, some seven miles below the source of that river. They form there a greatly crushed anticlinal fold, the same which is seen lower down the Dhauli Valley to consist of upper carboniferous, where the river in its downward course exposes the beds of the trias, permian and carboniferous in succession.

Continuity of structure, lower Lissar

The sequence of the strata remains much the same lower down the valley, though the structure of the flexures differs somewhat. The anticlinal, along the axis of which the Lissar river is running in its upper course, is south-west of the river and the reversed synclinal, which may be followed along the entire right side of the Lissar valley, is seen to be more than two miles from the river-bed. The section differs also in this, that the folds on the right side of the valley are all formed of silurian rocks (1, pl. 8). The band of bright coloured red quartz shales (3) which overlies the purple quartzites (2)[1] of the haimantas helps to illustrate the section, which would otherwise be very obscure, as the strata are not only very much crumpled but in some places crushed and faulted in every direction. The cliffs which overhang the right side of the valley belong to the upper silurians,

[1] The number (12) near the south-west termination of the section 1, pl. 8, should be corrected to (2) of the haimanta system.

and they dip from 30 to 40 north-east below dark devonian limestone; this latter is traversed in every direction by white calcspar veins, and has not yielded any fossils beyond some fragments of *Encrinites*. This is conformably overlaid by the members of the carboniferous system. The range between the Lissar and Dhauli Ganga forms here a simple synclinal, which incloses the permo-trias and rhætic group, the continuation of the great permo-trias strip already traversed in the former sections. There is a good deal of local crushing and faulting observable, but the throws are not of sufficient importance to be entered on the map.

The lowest trias (*Otoceras* stage) (10) with the underlying *Productus* shales (9) seems to rest conformably on the upper carboniferous white quartzite (8), which near the boundary with the *Productus* shales has a few beds of dirty grey sandstone in thin beds. The detailed section of the beds close to the boundary is in *descending* order:—

		Thickness Feet.	Thickness Inches.
Lower Trias Otoceras stage (10)	8. Shales, dark grey, with partings of irregular limestone beds	4	0
	7. Limestone, dark grey to brown with *Pecten* sp.	0	4
	6 Calcareous shales, dark grey	0	6
	5. Hard splintery dark limestone	0	2
	4. Friable grey, calcareous shales	0	3
	3. Shaly limestone		9
	2. Hard splintery dark limestone, fossils of *Otoceras* stage	3	0
	1. Alternation of dark, nearly black shales and limestone in thin beds about	150	0
Productus shales, Permian (9)	Black friable shales with ferruginous partings, weathering brown	238	0
Upper Carboniferous (8)	Irregular beds of grey quartz-sandstone. White quartzite in massive beds, etc.		

The descent into the Dhauli Ghanga valley is over the same section, and over the upturned and highly inclined edges of the beds composing it. The Dhauli Ganga flows there (near Dawe encamping-ground) along the axis of a synclinal formed of the white quartzite (8). The continuation of the section towards north-east is across a series of crushed flexures, greatly broken up by

local faults, and the interpretation of which is not at all easy, but which I will endeavour to illustrate further on.

The ranges of Dharma and Byans.

The hill-ranges which form the watershed between the Gangetic drainage and Tibet, with the numerous parallel chains to the south of it, all run in a more or less south-easterly direction from the head water region of the Dhauli (Dharma) Ganga. It proved a most difficult ground to explore geologically, and much of it being almost entirely inaccessible, besides which, one has to carry all one's supplies along, as there is not a single inhabited place in that area. I found that the structure of this part of the Himálayas is very similar to that of the area immediately north-west of it, of which it is a continuation.

A series of flexures may be observed between the crystalline base south, and the Húndés frontier, but it will be seen from the sections in pls. 8 and 9 they are much more compressed and disturbed than has been the case in the Lissar region, and a succession of faults of greater or lesser stratigraphical importance render the interpretation of the structure still more difficult. Three features characterize the Dharma and Byans area. First, the silurian system is only seen along the margins of the belt of sedimentary rocks, namely, accompanying the strip of haimantas along the southern margin, whilst some patches of silurian rocks form part of the high range of the water-parting between Tibet and the Ganges drainage. Secondly, the largest portion of the ground is occupied by rocks belonging to the devonian and carboniferous systems. Thirdly, the permo-trias forms only narrow strips crushed into synclinals of upper carboniferous rocks.

I have already described the structure of the flexures which form the highly elevated region of the head waters of the Dharma valley, which is represented in section 4, pl. 7. That is the only section in this part of the Himalâyas in which some remains of the jurassic Spiti shales were met with; further south-east the

younger mesozoic rocks have all been removed by extensive denudation.

Dawe sections.

Some ten miles south-east of the Dharma peaks amongst which the Dhauli Ganga rises, the section across the valley is very instructive. The Dhauli Ganga runs along the axis of a steep anticlinal formed of upper carboniferous rocks, chiefly the white quartzite (8), (see 2, pl. 7), followed north-east by a series of steep and often reversed flexures, within which in a highly plicated synclinal, or rather series of them, are inclosed the permian *Productus* shales, and the whole lower and part of the upper trias. The feature is given diagramatically only in the section quoted; how intricate the folding of the strata is will be seen in the heliogravures pls. 17 and 17 a. The profile is thus exposed, some four to five miles north-west of Dawe encamping ground, on the left side of the valley. As in all similar crushed folds, the soft shales of the *Productus* beds (9) and the overlying *Otoceras* beds (10) are greatly disturbed and completely crushed within the plications of the neighbouring harder strata. North-east of this permo-trias synclinal follow a series of reversed upper carboniferous flexures, inclined towards south-west.

The flexures may be followed downwards in the valley; some few miles south-east of the last described section, about two miles above Dawe encamping ground, the anticlinal of upper carboniferous rocks has been partly eroded by the Dhauli river, 1 pl. 8, and is flanked on each side by a synclinal of the same rocks, inclosing permo-trias sections. The one on the right side of the valley is a continuation of the rocks already described. The reversed synclinal on the left side of the valley forms the south-eastern continuation of the crumpled fold seen in section 2, pl. 7, and pls. 17 and 17 a; but here only some crushed remains of the *Productus* shales (9), and the overlying *Otoceras* beds (10) are left, whilst still further south-east denudation has removed every trace of the mesozoic rocks (sec. 2, pl. 8). The reversed synclinal on the left side of the Dhauli valley may be followed up continuously almost, and can be traced

across the high range which forms the divide between the Dhauli and Kuti Yangti valleys, is seen very clearly near the Lebung pass, and is finally lost in the tract to the east of that locality (see pl. 8, 1 of pl. 9 and pl. 18).

Reversed flexures of palæozoics, north-east of Dawe.

North-east of this strip of permo-trias above Dawe (1, pl 8), follow several reversed flexures of palæozoic rocks; south-west of the Lohi glacier, some remains of an anticlinal of upper silurian quartzites and greenish shales with fossils (5) is well seen in profile, and gives a clue to the rest of the structure. The ranges north-east of it are so encumbered by glaciers and their debris, that nothing is visible but a series of beds with seemingly isoclinal bedding, but belonging to the various members of the palæozoic group, carboniferous apparently dipping below silurian. I recognize in this structure the south-eastern continuation of the folds seen higher up the valley.

Mankshang sections.

The geological structure of all the high ground lying between the last described section, and as far east as the Mankshang pass, is difficult to unravel, as only the highest part of the ranges exhibit the rock *in situ*, the lower slopes being almost invariably covered by immense deposits of debris, generally of glacial origin, whilst the valleys are nearly always filled with glaciers and their moraines.

The section between Dawe encamping ground and the Lankpya Lek (...Langpaia Lek?), 2 of pl. 8, follows the track from Dawe to the Dharma pass, a difficult and often break-neck path, encumbered with much snow. The range which closes the valley of the Nui glacier to the north (right side) exhibits the structure partially, which seems to correspond with the one of the Lohi glacier valley, two miles to the north of it. The anticlinal of the Dhauli Ganga valley has been eroded down to the brownish red earthy *Crinoid* limestone (7, a) of the carboniferous, and for a few miles to the north-east the section is pretty clear. A reversed synclinal flexure, followed by a very much plicated and also reversed anticlinal is fairly well observable near the western end of the

Nui glacier valley. The lowest rocks exposed near the centre of the anticlinal are the upper silurian quartzites and shales (5), which cannot be mistaken. Fossil traces are many, mostly of *Orthis sp.* and *Corals*. This is overlaid by the dark-blue limestones (6) and further on by the carboniferous limestones (7) and white quartzite (8). The beds are all highly inclined, the flexures leaning over to south-west. The centre portion of the section is less clear. There is a great deal of local faulting and squeezing of beds out of the normal position, which I tried to indicate diagramatically in the figured section. But as far as can be seen, it is again a system of narrow reversed folds, in which the upper silurian series occupies the centre of the anticlinals. The flesh-coloured quartzites with greenish-grey shales (5) are flanked symmetrically by a sequence of dark devonian limestone (6), and the carboniferous rocks, which on the eastern side of the Dharma pass are succeeded by the permo-trias. The ground between this point and the Lankpya Lek is quite impracticable for the geologist; it is almost entirely covered with snow and small glaciers. But as far as I could make out, there seems to be a fault in that area, which has cut off the permo-trias (see 2, pl. 8), for I found palæozic rocks apparently overlying the trias in normal order, near the crest of the range (about 19,000 ft.) east of the Dharma pass. Beyond that I believe several flexures of the palæozoic group of rocks follow, the points flanking the Lankpya Lek being formed of the white compact quartzite (8) of the upper carboniferous series.

Permo-trias of Dawe.

Much clearer is the structure of the Dhauli Ganga valley, about four miles south-east of Dawe encamping ground. I have represented the structure in 3, pl. 8. The anticlinal of the Dhauli valley is there in reversed position, leaning over to south-west. The plication of the rocks, which compose the dividing range between the Lissar aud Dhauli Valleys, has resulted in a double synclinal, in one of which the south-eastern extension of the strip of permo-trias bed (see map) appears, only the black *Productus* shales (9) with patches of the lowest trias (10) remaining. This structure of the double synclinal may be traced in all the sections

across this range (see former sections). It is exceedingly well seen in the profile exposed by the Bankuphu glacier, and in fact may be observed for miles up and down the valley from near the Pungrung encamping ground.

Near Pungrung.

North-east of the Dhauli Ganga, near the Pungrung encamping-ground, the section exhibits a structure similar to that higher up the valley but with slight variations. The small glaciers which descend into the Dhauli valley near that place have laid bare the stratigraphical features; the synclinal of upper carboniferous white quartzite (8), which I have traced along the whole left side of the Dhauli valley appears also here, reversed leaning over to south-west, and inclosing some crushed *Productus* shales (9). A second synclinal of white quartzite (8) is crossed near the eastern ridge of the range, and it also contains permo-trias rocks, greatly crushed. It is the synclinal which runs south and south-east in a great curve from the lofty points between the Dharma and Lankpya Lek passes, and which I lost sight of in the rugged mountain ranges east of the Lebung glacier. In this permo-trias synclinal, the soft crumbling permian *Productus* shales (9) are constant along the entire length in which I traced the flexure; so are members, if not the whole series, of the dark limestones and shales of the *Otoceras* stage (10) of the lower trias. But the overlying light-grey compact limestone with Muschelkalk types (11) and the higher triassic black limestone and shales with *Daonella* sp., are only met with in the broader parts of this synclinal trough. In the middle length of the flexure, due east of Pungrung, and near the easternmost end of it beyond the Lebung glacier, I failed to identify more than the lower members of the system. These rocks cannot be mistaken for any other. Dark, many of the beds black (9, 10 and 12), they form jagged points and high peaks, sharply defined from the underlying white quartzite (8), and so form perhaps the most easily recognized rock series in the Himálayas.

Between the two synclinals just described runs a great anticlinal, often, as, for instance, east of the Dawe camping-ground, running into

several plications and anticlinals. The upper part of the arch, with the permo-trias and upper carboniferous series having been worn away, the reversed flexure which seems to form the main mass of the range between the Dhauli and Kuti Yangti, is made up of the lower carboniferous limestone (7 and 7*a*) and the compact, black limestone (6) of the devonian.

Carboniferous of the Kuti Yangti.

The north-eastern slope of the range down to the Kuti Yangti is chiefly built up of a series of highly compressed flexures of carboniferous rocks; the lower carboniferous red *Crinoid* limestone (7) shows in strong contrast to the neighbouring white quartzite. It forms a band of dull brownish-red, which may be traced from near the Lankpya Lek to some miles east of the Lebung pass, always keeping on the north-east slope of the range. It might in most places be taken as being intercalated between the beds of the white quartzite (8), but forms in reality a more or less compressed anticlinal (see fig. 25).

Folds with permo-trias.

In one of the synclinals of the white quartzite (8) members of the permo-trias are preserved. The trough runs along the Kuti Yangti valley, where I traced it on the right side of the valley, from near the Wilsha camping-grounds to Raráb, where it crosses the valley and is seen on the south-west slopes of the range, which forms the left side of the Kuti Yangti valley along the greater length of its course. It is rather a system of closely laid folds than one synclinal, but the distribution of the various divisions of the inclosed permo-trias could not be shown in a small scale map. It seems at first sight to be an alternation of permian *Productus* shales (9) with the overlying *Otoceras* beds (10). The section 3, pl. 8, crosses this synclinal strip about 2 miles south of the Wilsha camping-ground.

East of it I entered a very disturbed and difficult tract of country, chiefly made up of palæozoic rocks. Several of the carboniferous white quartzite (8) folds with inclosed *Productus* shales (9), and remains of *Otoceras* beds (10), are seen in perfect profile along the steep scarp which forms the left side of the upper Kuti Yangti river,

Fig. 25. Flexures seen north of Thumka Gádh, looking north-west.

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a few miles south of the Wilsha camping-ground. The heliogravure, pl. 21, shows part of this profile.

It is next to impossible to accurately describe this intricate and much faulted area, and I must therefore leave the figured sections 3 and 4, pl. 8, to speak for themselves. Of course one can only render the structure in a diagramatic manner. The ranges which form the Mankshang valley reach heights of over 20,000 feet and are nearly inaccessible in most places, whilst the easier slopes are covered by eternal snow-masses. The intensely red *Crinoid* limestone (7), the overlying white quartzite (8), and strips of black *Productus* shales (9) in the synclinals of (8), all of them visible at a great distance, help to interpret the structure of this range. All the rock systems have been subjected to immense plications and crushing, resulting in numberless more or less important, and generally reversed faults.

Mankshang glacier.

The gently sloping Mankshang glacier fills the upper portion of the valley and forms one of the passes into Tibet (nearly 20,000 feet sea-level); a general view of it is given in the heliogravures, pl. 22 and 22*a*, which together form one profile. The glacier is flanked by the carboniferous system, the white quartzite (8) forming the high points on each side, whilst the dark devonian limestone (6) must form the lower slopes and the saddle of the watershed itself, as is proved by the hillocks which stick out from the surrounding glacier ice (see views).

Rama and Takachull heights.

The Rama and Takachull group of peaks, ranging from 20,000 to 21,000 feet elevation, send out mighty spurs to the north, north-west and north-east. The dividing range between the Dhauli and Kuti Yangti valleys which runs nearly due north-west to south-east culminates near its two extremities in lofty ridges; north-west about the Dharma passes, south-east in the Takachull points. Most of the latter lie in the belt of the haimanta system already described. Between the Rama camping-ground on the Dhauli Ganga and the Kuti Yangti valley (see map), a band of the bright red quartz shales (3) is accompanied by dark quartzites and dark-grey *Coral* limestone (4) which belong un-

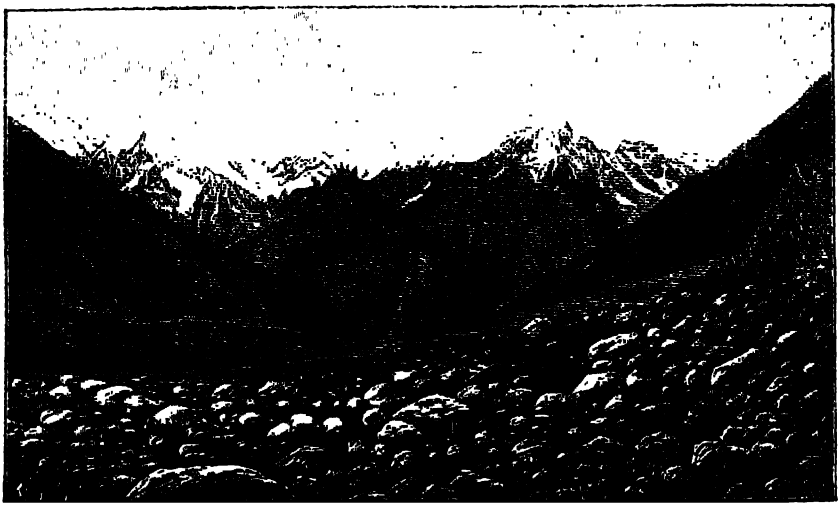

Fig. 26. The Palæozoic group, west of the Lebung glacier.

mistakably to the lower silurian. In normal succession follow all the members of the palæozoic group, though subordinate plications and local faults may be constantly observed. I could do no more than reconnoitre that palæozoic belt from the two ends,—near the Lebung glacier. and in the valley of the Kuti Yangti (see fig. 26). There are no villages anywhere in this elevated district to form points of appui for excursions, supplies, etc., and an extended stay amongst these snow-covered ranges is almost out of the question, and would scarcely repay the immense trouble, as most of the accessible ridges are either snow or débris-covered. In section 2, pl. 9, I have endeavoured to render the structure diagramatically.

The route (a very risky and dangerous track) from near Rama camping-ground, to Jolinka camping-ground in the Kuti Yangti, traverses the system of flexures at right angles to their strike. One after another I traversed along this path the flexures described from higher up the valley, but the belt of sedimentary rocks must have suffered greater pressure and consequent greater local disturbance than further to the north-west. Section 1, pl. 9, I believe fairly

represents the actual structure of the range at the Lebung pass, though it varies locally every few hundred yards and is faulted in every direction (see pl. 20). A series of flexures of carboniferous limestone (7) and white quartzite (8) incloses some members of the permo-trias. On the north-east slope of the pass, a fault cuts off the letter and carboniferous red *Crinoid* limestone (7*a*) abuts against the highly inclined permo-trias. The view, pl. 18, shows part of the range which incloses the Lebung glacier to the southwards, formed of one of the many anticlinals of carboniferous rocks, followed south-west by a synclinal fold inclosing some permo-trias beds.

Pl. 19 may to some degree convey an idea of how difficult geology becomes in those heights. The view (photograph) represents the upper part of the Lebung pass, which is quite impassable for baggage animals, and is even very difficult for lightly-laden coolies. In summer avalanches constantly descend from the left (right in the picture) side of the pass, often burying under snow and stones large numbers of men and sheep who may happen to be crossing at the time.

Lebung sections.

In the sections 5 of pl. 8, and 2 of pl. 9, I have endeavoured to give my interpretation of the structure of the Dharma hill-ranges as it appears about 2 miles north-west, and 5 miles south-east of the Lebung glacier. The first-named section is a good type of the complicated structure of the Dharma and Lissar ranges, and I have therefore carried it on to the high snow-covered peaks south-west of the Lissar river, from which the Naulphu and Nipchung glaciers descend into the Lissar valley near Marcha and Sepú. Across the Dhauli Ganga and Kuti Yangti the section is very similar in general detail to the one between the Bankuphu and Mankshang glaciers (3 pl. 8), except that the high ranges north-east of Raráb encamping grounds in the Kuti Yangti are entirely made up of carboniferous rocks, which are very much disturbed and folded.

Section 2, pl. 9 (see also fig. 26), from the Rama heights across the Kuti Yangti valley in a north-east direction traverses the palæozoic group, which I have only been able to reconnoitre from afar ; the upper

carboniferous white quartzite (8) is overlaid conformably by the permian black *Productus* shales (9), which about 2 miles south-east of the Sangchuma camping-ground are cut off by a reversed fault, white quartzite (8) being again pushed over it. This is evidently the same fault as observed five miles off on the north-east slope of the Lebung pass.

Bithir Gádh.

Several streams (Birthir Gádh, etc.) rise amongst the high ranges which divide Tibet from this part of Kumaun, amongst which points of over 21,000 feet occur; these streams unite, and flow in a deep gorge into the Kuti Yangti; exhibiting good sections during their course. On entering this gorge I found myself traversing a large reversed synclinal, or rather system of synclinals, of carboniferous rocks, white quartzite (8) which incloses again a good section of the permo-trias. The black *Productus* shales (9) are less friable and contain more limestone partings. The overlying lowest trias (*Otoceras* stage (10) is a succession of hard limestones of dark-grey colour, with scarcely any shales to divide them. About 100 to 150′ of very hard light-grey limestone, with sections of *Ammonites* on the weathered surfaces, represent the middle trias with Muschelkalk types (11), lithologically not different from the same beds elsewhere further north-west. Overlying it I found very hard, dark, almost black limestone in thick beds, in which I did not see a trace of fossils. Numerous calcspar veins traverse it and its general aspect is not unlike the devonian limestone (6), but its position in the synclinal overlaying the lower triassic rocks clearly indicates it as the representative of the upper triassic *Daonella* limestone (12). Proceeding further up the Thumka Gádh gorge, I came upon a succession of palæozoic beds as indicated in the figured section 2, pl. 9. From the presence of the red *Crinoid* limestone (7, a), inclosed within a great thickness of white quartzite (8), it seems to me evident that I traversed there two more, and moreover highly compressed, reversed flexures. A descending section from white quartzite (8) down to the bright red quartz shales (3) below which

haimanta rocks appear, indicates that the higher part of the Bithir Gádh and Thumka Gádh ranges are formed by the remains of an immense reversed anticlinal, leaning over to south-west, whose upper portion has been eroded.

Trias synclinal of the Kuti Yangti.

The permo-trias of this section may be traced without interruption from south of the Wilsha encamping ground to the lower Kuti Yangti valley. The synclinal in which they are met with shows some plication within itself, and here and there several distinct folds may even be found. A very instructive section across this system of synclinals I found north-east of the Jollinka encamping-ground about 3 miles north-west of the Thumka Gádh.

The feature is shown in the 3rd section, pl. 9, and in fig. 25. The upper carboniferous white quartzite (8), with the permian *Productus* shales (9), and lower trias beds (10), is laid into such narrow folds, that the whole presents rather a complex of alternating beds of black shales and white quartzite with isoclinal dip. Facing the cliff, on whose south-west face the beds are well exposed one might take it as a sequence of beds, the black shales and limestones of the permo-trias being interstratified with the carboniferous white quartzite, if one of the numerous ravines did not conveniently cut through the beds at a right angle to their strike, and so make clear the structure as seen in the figures mentioned. The folds are reversed and leaning over to south-west.

The Upper Kali river sections.

The ground south-east of the sections already described and drained by the head-waters of the Kali river, differs in structure in some points from the Dharma area. It will be remembered that the great heights north-east of the Thumka Gádh (2, pl. 9) are built up of a reversed descending section, the beds of which descend with a rolling dip to north-east. In connection with the facts already related, I understand this to be part of a reversed anticlinal, and the lower silurian limestone which forms the highest points of that range to be the cen-

tre of the flexure, whose upper arch has disappeared by erosion. The anticlinal may be traced in a south-east direction, and its axis followed along the rugged heights which form the south-west slopes of the dividing range between Kumaun and Tibet.

Anticlinal of Tera Gádh.

It may be recognised again in the reversed anticlinal north-east of the Tera Gádh (4, pl. 9), in the much plicated anticlinals between the Lilinthi grazing ground and the Húndés frontier N. by E. (8, pl. 9), and lastly in the anticlinal of devonian and upper carboniferous rocks south-west of the Lipú Lékh (pass) (5, pl. 9). In spite of extensive faulting in this ground, sufficient is left of this flexure to show its true structure. The strip of ground immediately following north-east of the anticlinal is formed chiefly by the upper side of the reversed fold, and is therefore an ascending section, reaching at some points to the rhætic, as is shown in the diagram named.

Between this reversed anticlinal, and the ill-defined boundary of the lower silurian with the underlying haimantas, the general feature of the Dharma and Lissar sections is reproduced, accompanied by much faulting; in the figured diagrams on pl. 9, I have tried to show some of the complicated character of the folds and accompanying faults. Enough is seen of the very disturbed structure (see pls. 24, 25, 26 and 27), to show that the plications are rather more complicated than given in the diagrams. The two principal permo-trias synclinals of the Dhárma valley may be recognized in the upper Kali river sections in several detached strips of irregular outline, within which the beds, ranging from the permian *Productus* shales to upper trias, are found to be much crumpled (see pls. 26 and 27) and crushed. The belt within which these synclinals are found has been most affected by faulting, part of the folds having been let down along lines which coincide more or less with the general direction of the strike, except near the ground west and north-west of the Tera Gádh, where a portion of the trias-rhætic strip has been let down by faulting, whilst palæozoic rocks have been pushed over the former; the actual features exposed are shown in 4, pl. 9.

Palæozoics of the Kali river.

The Kali river from about two miles north-east of Kaua Malla to three quarters of a mile above Kalapáni encamping-ground passes chiefly through rocks of the palæozoic group. It is a normal ascending section, though the beds composing it are greatly disturbed. This feature is exposed in the high, partly wooded, hills which bound the Kali river on its right side (pl. 25). The hills are of fine bold outlines, and one of its prominent points rises to 17,634′. The top of this peak is made up of upper carboniferous white quartzite (8); below it the lower carboniferous series, red *Crinoid* earthy limestone (7, a) and dark-blue and dull-grey limestone (7), with large *Crinoids* and *Brachiopods* is conspicuous; the carboniferous system rests on lower palæozoic rocks, all highly plicated and crushed. In the upper silurian quartzites some poor fossils, mostly casts of *Orthis*, are common; but the lower silurian beds, although represented, as shown by débris found in the immense fans, I could not study in detail, as both the great undercliffs of loose material and the wooded condition of the lower spurs prevented close work. How complicated the folding is may be estimated from the heliogravure pl. 25, which shows some of the folds of the upper carboniferous quartzite (8), about a mile south-west of Kalapáni on the right side of the Kali river.

Fault of the Panka Gádh.

Near this point I observed much faulting which south-east resulted in letting down part of the permo-trias, which has thus been preserved from denudation. This is the small patch on the left side of the Panka Gádh (7, pl. 9) which consists of a greatly folded series of beds, from the permian *Productus* shales (9) to upper trias. The beds have suffered greatly by crushing and are in consequence traversed in all directions by joints; fossils are rare and, when found, generally distorted or fractured. But the general lithological character and succession of the beds is the same as in the Dharma-Lissar sections. The system rests apparently conformably on the upper carboniferous white quartzite (8). The latter partakes of the highly folded character of the area, and is followed north-east by the great synclinal, or system of syn-

clinals, of permo-trias seen in section 8, pl. 9. The sequence of beds is the same as in the Panká Gádh, but the upper trias is followed by the entire rhætic system up into the *Lithodendron* limestone, with zones of Kœssen fossils. Several parallel faults, more or less north-west by west, to south-east by east cut up the synclinal into several blocks, complicating the horizontal projection of the boundary lines beyond the possibility of rendering them on the map except diagramatically. South-east of the Lilinthi grazing ground the permo-trias section, though disturbed by faults, is a normally descending one, and the black *Productus* shales (9) are resting on white quartzite (8), all dipping under a high angle to south-west.

Between the Lilinthi grazing ground, and about 1½ miles north-east of Kalapáni, the Kali river runs along a line of fault (8, pl. 9), and upper rhætic beds, consisting of thick-beded dolomites and *Lithodendron* limestone, are brought in direct contact with carboniferous white quartzite (8), which has been pushed over the rhætic, so that in some sections the contact has the appearance of a normal one, and the white quartzite seems to overlie the rhætic. But following up the fault to west and north-westward, I found the white quartzite (8) in similar position, pushed over upper rhætic limestone, and in succession over all the beds of rhætic, trias and permian *Productus* shales (9), whilst still further in the Tera Gádh dark devonian limestone (6) is pushed over the trias and rhætic beds in succession ; sections 4 and 6, pl. 9, illustrate this feature, as also do the heliogravures pls. 26 and 27.

Many minor faults have produced complicated features in this belt ; the most complicated portion of the latter is the one lying west of the Kali river and forming the right side of the Tera Gádh. In addition to the permo-trias, with rhætic, being laid into minute and often gigantic and close folds, the complex of beds is also jointed and faulted. So, for instance, near the highest point of the conical hill north-west of Kalapáni (4, pl. 9), the lower carboniferous and trias section is several times repeated, and the whole might very easily be mistaken for an alternation of beds, if fossils were wanting.

Complicated structure Tera Gádh.

The beds pushed over the rhætic in the last-mentioned section form the upper side of the reversed anticlinal described at the beginning of this chapter, and are therefore a normally ascending series from devonian limestone (6) through carboniferous into the permo-trias, which forms the dividing range between Kumaun and Húndés. Lower down the Téra Gádh (4, pl. 9), and in the Kali river, north of Lilinthi grazing ground (8, pl. 9), part of the anticlinal arch has been preserved, but the latter is well seen south of the Lipu Lekh (5, pl. 9), where the faults disappear. There it is a gently rolling anticlinal, the lowest beds of which are formed by devonian, very dark limestones, containing *Encrinites*, some *Brachiopods* and *Trilobites*, and is overlaid by the whole carboniferous system; the hard white quartzite (8) forms the highest points on each side of the pass.

This palæozoic anticlinal is flanked on both sides by synclinal flexures, which inclose permo-trias rocks. The one to the south-west I have already described; the one to the north is a flat trough, inclosing the permian *Productus* shales (9), and a portion of the lower trias (*Otoceras* beds).

At the frontier the Tibetan authorities again obstructed my further progress, and so I could do nothing but get a glimpse of Húndés, as far as I could reconnoitre it from the range forming the boundary. In a north-east direction, extends a mountainous region which drains towards the Manassorawar Lakes, and as far as I could judge, it is formed for some distance by a succession of flexures, apparently of palæozoic rocks. The ranges in the far distance (see pl. 12) appear to be composed of crystalline rocks, whilst younger deposits in the shape of post-tertiary terraces fill the low valley below, in which the Tibetan town of Taklakar is seen to be built against the slope of one of these terraces.

This formed the extent of my geological reconnaissance of Kumaun towards the north-east frontier of it. Both Tibet and the adjoining Nepál are forbidden ground to all but Bhotea shepherds and traders

CHAPTER VII.—NOTES ON THE CENTRAL HIMÁLAYAS BETWEEN THE KAMET AND SPITI.

The survey of the Bhot mahals of Garhwál and Kumaun concluded my detailed work in the Himálayas, the result of several seasons' wanderings amongst these mountain masses. The work is laid down on Map No. 1 which accompanies this Memoir. But as I was desirous of effecting a junction with Stoliczka's early work in Spiti, I proceeded to reconnoitre the ground between Niti and that area, the result of which study will be described in the following pages and is recorded on Map No. 2 of this report.

1. Crystalline rocks and haimantas between Niti and Bisaihr.

The great mountain mass of the Kamet (25,443′) already alluded to in my description of the Niti gneiss, continues westwards to the Gangotri peaks and to the mountain masses beyond it. From it the immense glaciers of the Mána and Gangotri peaks descend down to the head-waters of the Sarsuti and Bhagirathi branches of the Ganges system; they help to make this mountain region one of the most inaccessible areas of the Central Himálayas.

As my task did not so much consist in an exploration of these snowy regions but rather to study the succession of the sedimentary rocks north of the central range, I had to content myself with a mere reconnaissance of the belt of metamorphic rocks and their boundary with the overlying older palæozoic systems.

Boundaries of the haimantas.

I have not been able to settle satisfactorily in what relation the haimanta system stands to the underlying crystalline rocks in the area north-west of the Kamet masses. Two points, however, are quite clear; first, that the upper boundary of the haimantas is a natural one, this system being overlaid conformably by, and passing into, the lower silurians; and secondly, that the boundary between the crystalline rocks and the haimanta system is obscured by intrusive granite, which is here developed on

an abnormally large scale. Generally speaking the granite forms large masses in the Central Himálayas, and has penetrated as a complete net-work of veins and dykes into the neighbouring strata. In this manner part of the haimantas have been changed into a more or less crystalline rock.

Granite; intrusive.

This granite, whether found developed as a great mass, as, for instance, in the Gangotri peaks, or found as fine net-work in the gneissose series, contains usually plagioclase felspars, notably albite. It often assumes a porphyritic appearance with large twin crystals of felspar. It contains frequently many accessory minerals, amongst which hornblende is commonest, and may be found all along the belt of granitic intrusion. Besides this beryl tourmaline, garnet, and kyanite are found in it in many localities, between the Bhagirathi and Sutlej. Some bosses and branches of the main mass of granite are distinctly dioritic, which feature is especially well seen north-east of Nilang. It forms the great mass of the Badrináth, Kedarnáth and Gangotri peaks, and is seen in immense development south and west of the Shipki pass. Near the contact of it with the metamorphic rocks and the haimantas, the granite penetrates as an immense net-work throughout the adjoining strata. Near the contact the sedimentary rocks are further altered, often into a finely crystalline micaceous schist, or, as, for instance, near Nilang village, where it has been changed into a hornblendic rock.

Forms an irregular belt.

It forms an irregular belt, sometimes forming a compact mass, such as composes the magnificent peaks and mountain groups of the Mána, Gangotri and Kedarnáth region, which rise to upwards of 25,000 feet, but oftener forming smaller centres surrounded by a system of smaller intrusions. Such is best seen in the area between Nilang and Shipki.

Shipki pass; granite intrusions.

The road over the Shipki pass leads over one of these granite centres, and how intricate the net-work of minor intrusions is may be seen in figure 8, which represents the grand precipice on the right side of the Sutlej valley.

viewed from between the village of Namgeah, and the south ascent of the Shipki valley. The felspar contained in this granite is represented by white albite, and as accessory minerals I found beryl and kyanite freely disseminated throughout the rock. As far as I could ascertain, this same granite, often inclosing masses of altered sedimentary rocks of greater or lesser extent, forms the hills on both sides of the Sutlej valley near Shipki, extending far to the south and north. Further eastwards on Tibetan ground the sedimentary series follows in normal order.

To follow up the intricate and often indistinct boundary of the granite intrusions with the neighbouring strata, would have required a great deal more time than I could devote to the entire work of Himálayan exploration, and I had therefore to content myself with establishing the fact that such granite intrusions do exist near the base of the haimantas, and not only obscure the latter, but penetrating them and convert the shales and phyllites of this system into a more or less metamorphic series. I found it therefore impossible to do more than indicate on the map, partly diagramatically, how this boundary runs, and further I found it more convenient to distinguish on the map No. 2 with one colour (pink), not only granite, but also the various crystalline rocks which make up the main ranges of the higher Himálayas, amongst which a grey gneiss with hornblende is the most prominent ("Central gneiss" of Stoliczka) rock.

The Nilang sections.

The Bhagirathi river exposes a good section through the crystalline rocks of the Central Himálayas of Tihri Garhwál. South-west of Nilang, practically the only rock traversed is granite, and granitic gneiss with isolated masses of schists. The dip of the latter and the granitic gneiss, where bedding is visible, is almost uniformly to north-east, varying from 45 to 50°. Between Batwari and Jalah, the prevailing rock is a grey gneiss in thick beds, in which occasionally beds of micaceous and chloritic schists are

Granite south-west of Nilang.

Gneiss of Batwari.

intercalated. Numerous intrusions and bosses of hornblendic granite are found both in the grey gneiss and the schistose beds of Jalah; I found they increased in frequency and importance as I neared Derali (east), and about a mile north of that place the finely crystalline grey gneiss, and beds of hornblendic schist, are in abrupt contact with hornblendic (albite) granite, the same rock, which forms the main mass of the great peaks east of it, namely, the Gangotri and Kedarnáth heights. On the right side of the valley the boundary between these rocks is plainly visible; the gneiss dips north to north-east as before, and the granite forms a solid unstratified mass abutting against the former. I found numerous lumps and fragments, often of very large size, of grey gneiss and hornblendic rock included in the granite near the contact of the latter with the metamorphic schists.

Hornblendic granite intrusions.

Between Nilang, and a mile west of Jangla, the Bhagirathi with its large tributary, the Jádh Ganga, has eroded deep gorge through the great granite mass which, as I have already shown, stretches from the Kedarnath heights in a north-west direction towards Nilang. The gorge is one of the most remarkable ones in the Central Himálayas, and for picturesqueness can hardly be surpassed by any valley in the world. Its sides are often absolutely vertical, smoothed down by the torrent, which rushes six hundred and more feet down below, through a narrow slit in the rock. At the narrowest and most picturesque spot (Bhaironghati) a wire suspension bridge spans the gorge, which affords a means of reaching the Gangotri temple and glacier. This bridge has been erected by a forest officer, and is, perhaps, one of the best examples of amateur engineering in existence.

Gorge of Bhagirathi in granite.

From that point the granite mass extends far to the east,—in fact is continuous with the Kedanath and Mána mass; but some few miles (six to eight) north of the Bhagirathi valley I found the rock changed to semi-metamorphic schists, quartzites, and slates, which probably belong to the same formation as the schists which overlie the gneiss of

Continuous with Kedarnath and Mána granite.

the Nanda Devi, and which I have separated for the present from the rest of the metamorphics as the vaikrita system. How far this may be the case must be left to future researches. I found the region north-west of Nilang inaccessible with the means I had at my command, and had to content myself with including these semi-metamorphic beds in the haimantas which play a great *rôle* in the Nilang area. The boundary of these rocks with the granite as drawn west of Nilang is purely diagramatic; not anywhere is the boundary well defined,—in fact the granite seems to pass through a gneissic stage into the felsites and quartzites of the vaikritas or haimantas of that area.

Nilang. Granite.

Arrived at Nilang, I observed the following: the valley widens there and several smaller side ravines, filled with glaciers, send down large accumulations of moraine matter which spread themselves into the Nilang valley itself. There part of these clays and boulders have been re-deposited, and form a fairly extensive undulating patch of land, which is cultivated by the Nilang people. Granite forms the surrounding hills of the Nilang valley itself, but the semi-crystalline slates of the vaikritas and haimantas are seen to form the upper part of the hill range which extends on the right side of the Jádh Ganga to near the village of Nilang. The beds of this formation dip to north-east, though much disturbed, and the contact of the granite with the former is distinctly that of an intrusive rock. Veins and dykes of granite penetrate the slates in all directions near the contact, which is well seen just west of the village of Nilang The slates are evidently much changed near the contact with the granite; in parts quite crystalline, and generally showing a bright red belt of some fifty feet or more near the boundary.

The same granite is found in situ some distance up the valley; it constitutes the lower part of the ranges which form the narrow valley of the Mána Gádh, as far as about two miles east of Naga encamping-ground, near the junction of the Jádhang with the Jádh Ganga. I also found it some two miles north of Naga and close to Jádhang

village, but the actual boundaries of the granite cannot be laid down accurately on the map, as it penetrates as veins and dykes far into the neighbouring sedimentary strata, here and there completely replacing them, where it forms larger masses. Locally the character of the granite changes entirely, and it appears that dioritic masses replace the former. In what exact relation these dioritic outbursts stand to the granite I am at present unable to say, but the rock and its mode of occurrence reminded me strongly of a similar association of granite with dioritic rock near Bhim Tal in Kumaun, already noticed by General Strachey.[1]

Locally dioritic.

Some way up the Mána Gádh, about two miles east of Naga camping-ground, the quartzites and slates of the haimantas are seen to form the higher parts of the ranges inclosing the valley; they dip towards south-west against the granite mass.

Haimantas, east of Naga.

From the lower heights of the range, which divides the Jádhang from the Jádh (Nilang) Gádh, about three miles north of Naga, a very fine view of the surrounding ranges is obtained. The lower parts of the valley with the spurs of hills is formed of granite, whilst all the higher ranges near, mostly snow-covered, consist of highly contorted strata of the haimantas (see figs. 27 and 28), often twisted into the most intricate folds, but there is a general tendency apparent to dip to west or south-west under most varying angles. The granite penetrates this system in numerous intrusions, sometimes forming a perfect network of veins in it. But very little granite is seen north of Kúh encamping ground. That this rock must be found higher up the valley is shown by rolled boulders of it which are seen in the river.

The road to Pulamsúmda camping-ground, at the foot of the ascent to the Tsang Chok Lá (pass), passes mostly along the strike of the haimantas, and is consequently not a very instructive route to take. Nothing is seen

Section to Pulamsúmda, haimantas.

[1] Quart. Jour. Geol. Soc. 1851, VII, p. 298.

but silicious shales, often very friable, breaking up into needle-shaped fragments, clay shales, weathering brown with a few grey

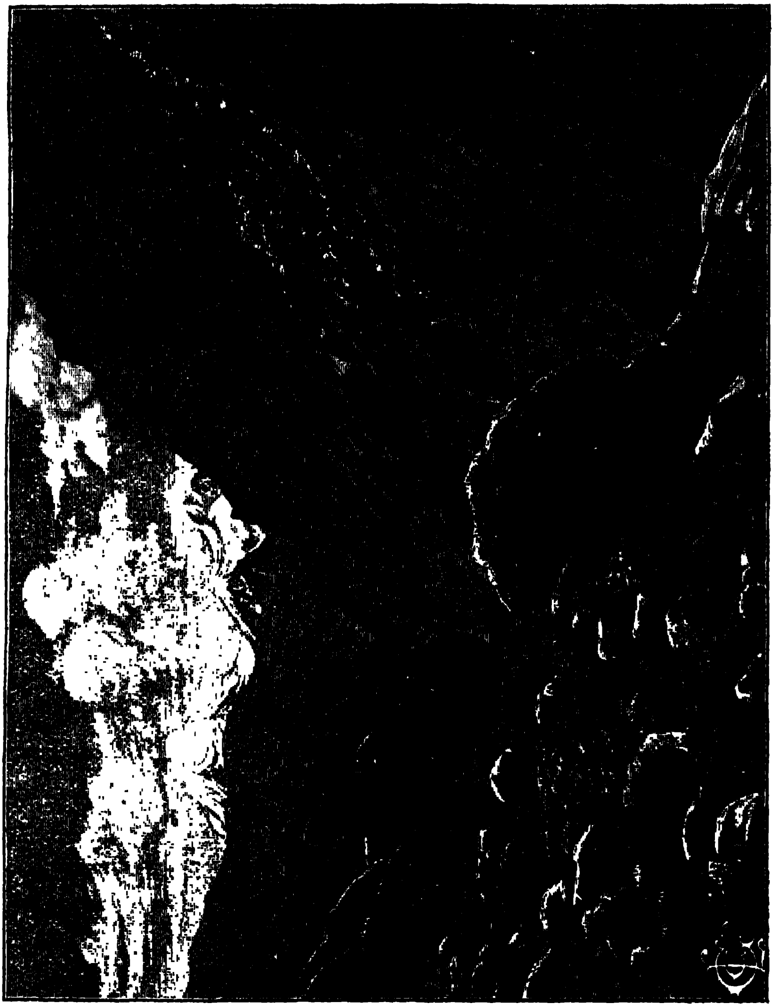

Fig. 27. The Nilang peaks seen from the road between Pulamsumda and Sonam camping grounds; haimanta conglomerate and quartzites.

limestone beds, and a great deal of quartzite of purple colour with the well-known quartz conglomerate which I first met with in the Niti sections.

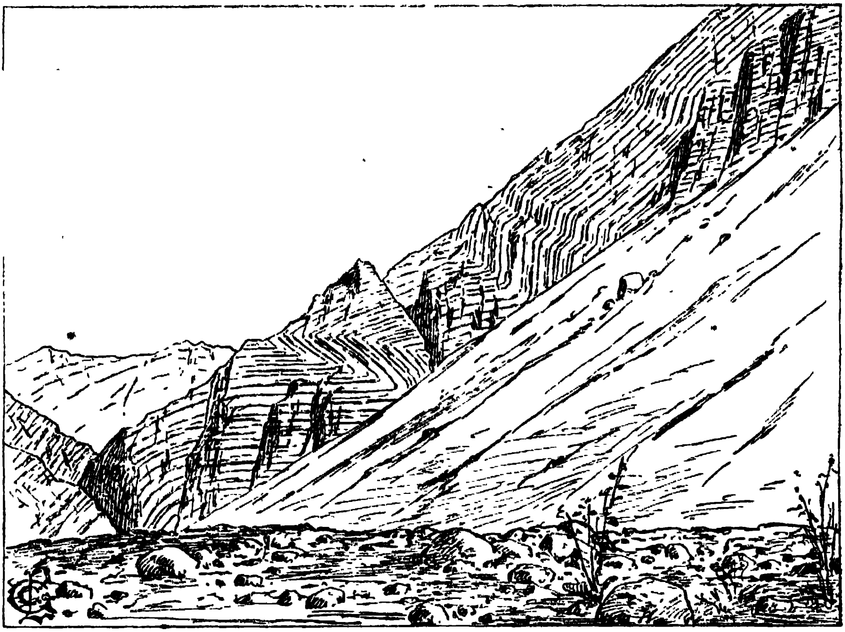

Fig. 28. Contorted haimantas between Sonam and Angera camping-grounds.

That the main mass of the strata between Naga and Pulamsúmda belongs to the haimantas I have little or no doubt, but the structure of the beds in that area is so complicated and disturbed, that it can be easily imagined that within the many folds of this system other formations of the palæozoic group may be represented, but to map these strips in this desolate mountain region would require years of work.

Red quartz-shales (3).

Between Angar and Pulamsúmda camping-grounds I noticed first the strata of the red quartz-shales (3) which closes the haimantas above. It is seen as a twisted, contorted red band along the hill slopes, and dips below dark fossiliferous limestones with quartzites east of Pulamsúmda. Here

we have the first clear indication of the lower silurians, which are seen in full force on the top of the Tsang Chok Lá (pass) itself.

Silurians near Mendi.

Near Mendi camping-ground the rock is lower silurian limestone, and dark greenish clay-slate, but I have no fossils out of it, with the exception of fragments of *Corals*. But the position immediately above the red-quartz shales (3) make its age apparent. Between Mendi and the top of the Tsang Chok Lá the prevailing rock is dirty pink quartzite, with greenish grey shales, the well-known upper silurian division. Enormous masses of débris cover up the last ascent to the pass, nothing of the rock in situ is seen there; but the cliffs overhanging the saddle of

Carboniferous of Tsang Chok Lá.

the pass itself are composed of white carboniferous quartzite (8). The descent of the pass to north-east into the Hóp Gádh (see pl. 11) leads over an entire section of palæozoic rocks; the Hóp Gádh itself corresponds more or less with a line of dislocations and the high cliffs which form the right side of the Hóp Gádh are formed of sections of the trias and rhætic.

The season was already too far advanced when I reached the top of the Tsang Chok Lá in 1882 to do more than reconnoitre Húndés from there; the thermometer at Mendi during the day rarely rose above 8° Fahr. in the shade, and of course all springs and streams were frozen, so that I had to retrace my steps rapidly not to become snowbound. I again visited the Nilang area the following year, and

Cross from Naga to the Changanmu Gádh.

this time, instead of ascending the Jádh Ganga, I branched off to east. From the Naga camp I crossed the range to eastwards into the Changanmu Gádh, a tributary of the Mána Gádh, by a pass which is over 19,000 feet above the sea, and gradually ascending the Changanmu stream, crossed a very high but easy pass into the upper Hóp Gádh. It is a route which, according to the natives of Nilang, used to be much frequented by shepherds some thirty years ago, but is absolutely never traversed now. Certainly it is a particularly difficult one, and the country for many marches is absolutely a wilderness, and mostly covered with snow. I found it much more instructive, however, than the regular

route to Tsaprang by the Tsang Chok Lá, as I traversed the strata mostly at right angles to their strike, and so obtained a better view of the stratigraphy of the area.

Folds of haimantas.

Between the Jádh Ganga and the Hóp Gádh I traversed nothing but fold after fold of much shattered haimantas; possibly some other members of the palæozoic group may have been inclosed in strips in some of the folds, but if so, I could not separate them in the map from the haimantas, which is the prevailing formation. They are mostly purple quartzites, greenish-grey phyllites and conglomerates. Being not only folded but much shattered, their dip is most confusing, but there is a general strike from south to north or south-east to north-west observable. Between the second pass ("pass to Muling, etc.") and the upper Hóp Gádh I passed Jessie's Lakes (fig. 6), calm sheets of water caused by the damming up of the valley by glacial débris, and surrounded by snow-capped rugged hills, formed of quartzites and slates of the haimantas.

Palæozoics of the upper Hóp Gádh.

After crossing a third and rather rough pass, I reached the upper Hóp Gádh, and with it other members of the palæozoic group. Both lower and upper silurian I could recognize; also the dark concretionary limestone of the devonian is here represented, the whole dipping to north-east.

Hóp Gádh fault.

The Hóp Gádh itself appears to correspond with a long line of fault, which may or may not be the continuation of the great Niti fault; at all events it is in the line of strike of the latter, and the probability of these two faults being one is considerable.

When moving down the valley of the Hóp Gádh, I found that the left side (see fig. 29) of the valley is almost entirely made up of the older palæozoics, whilst the right side presents the steep cliffs of rhætic, or rhætics with trias below.

Section through trias and rhætic.

A very good section through the latter I obtained in crossing the rugged cliffs on the right side of the valley to Dogkwa Aúr camping-ground. The first climb

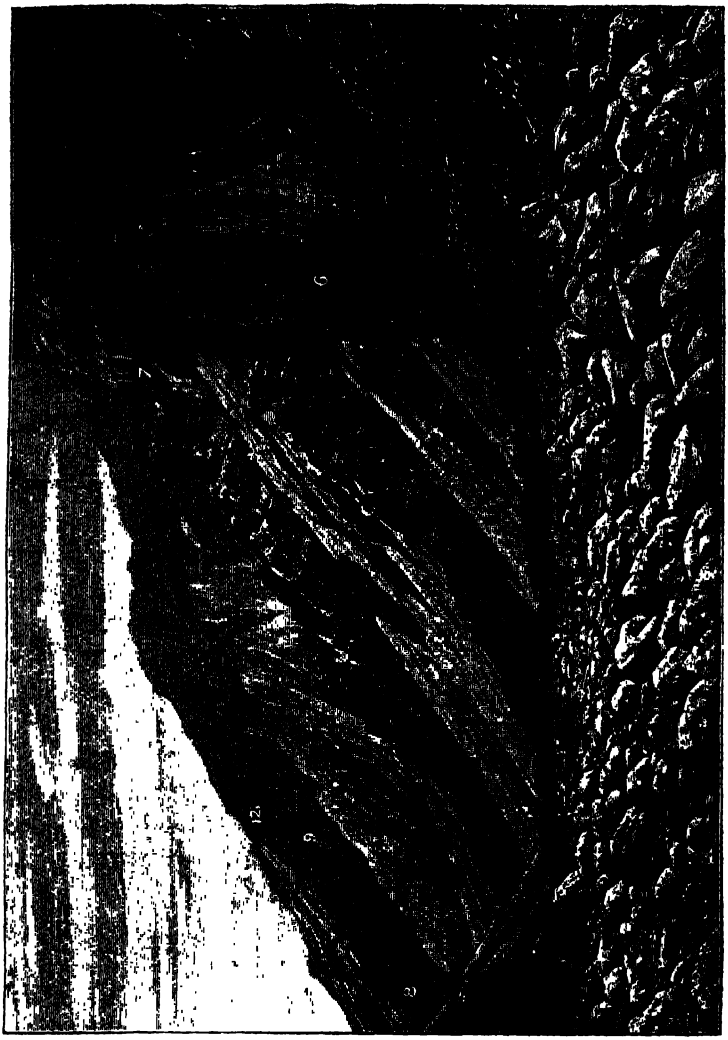

Fig. 29. Trias and carboniferous in the Hóp Gádh, Húndés; looking north.

up the steep triassic cliff (pl. 11) is difficult, and even dangerous in places, but the remainder of the way to the grazing grounds of Dogkwa Aúr is easy enough over rolling dip-slopes of upper rhætic.

The actual section of the trias and rhætic differs in no-wise from those already described from Niti, of which they are only the north-western continuations. I found here and there at the very base of the cliffs which form the right side of the Hóp Gádh, upper carboniferous white quartzite (8), overlaid by black *Productus* shales (9). And the latter are invariably followed by the entire trias, grandly developed, with the *Otoceras* beds (10) at their base. Fossils are common, and had I had more time at my disposal I might have made a very fine bag there, only I was daily sorely troubled by the Tibetan guard, which had discovered me in the Hóp Gádh, and whose object was to prevent my onward march to Tsaprang, and eventually Gartók. After days spent on various reconnaissances across the undulating rhætic hills around Dogkwa Aúr, I had finally to give up further explorations in that direction, not on account of Tibetan obstruction, but owing to the cowardice and scheming of my Indian followers.

Return march to Nilang.

The march back I accomplished by the Tsang Chok Lá (see pl. 11), which affords a fine view over the grand cliff of trias and rhætic, not less than the palæozoic sequence of the Tsang Chok Lá range or Jelukhaga. The dip of the latter sequence seems normal and below the triassic cliff, but there is good evidence higher up the Hóp Gádh that a fault, probably a fold fault, does run along this valley, for we have in places upper carboniferous white quartzite (8), pushed over lower silurian *Coral*-limestone (4), and possibly higher up, east of Jessie's lakes, over the haimantas.

The remainder of the march to Nilang brought me over the section already noticed. I should have liked to examine the area north and north-east of Nilang very much more in detail, but that was impossible; the ground is already claimed by Tibet as part of the province of G'nari Khorsum, or Húndés, and Tibetan guards were black-mail-

ing me daily though never offering violence. In addition to the political difficulties came the fact, that only recently three Tibetan beggar-monks had been murdered by the Nilang people, and relations between the latter and the Tsaprang authorities were strained.

The Spiti sections.

I had originally intended only to work out the geology of the Bhotmahals of Kumaun and Garhwál with the adjoining parts of Húndés when I begun my wanderings in the Central Himálayas. But finally I saw that it would be absolutely essential also to visit Spiti, in order to compare the structure of the regions already examined with Stoliczka's sections; I had hitherto failed to identify the systems and divisions of the Garhwál sections with those described by our late colleague, whose classification had found extensive use in later geological research in Kashmir,[1] and although I always believed that this classification would have to be modified, I possessed no proof that it was actually wrong on some points.

I was able to visit Spiti in 1883, and with it brought my labours in the Central Himálayas to a close for the time.

Spiti is classic ground; it had been visited and described by our eminent and late colleague Dr. F. Stoliczka. His published sections[2] have been until recently considered crucial ones for the geology of the North-West Himálayas, and his nomenclature had been largely applied to the geological structure of other regions of the Himálayas. I have myself no doubt that had Stoliczka been able to revisit Spiti, he would have modified his views on some points, and would, perhaps, have recognized certain horizons which he had overlooked.

After Mr. Lydekker had freely made use of Stoliczka's nomenclature, Mr. Oldham started on a tour through the Spiti valley and North-West Himálayas with a view of correcting certain points in the geology of those regions which appeared to require revision. Unfortunately he did not devote enough time to the sections of Spiti;

[1] Lydekker, Memoir Geol. Surv. Ind, XXII. (1883).

[2] Mem., Geol. Surv. Ind., V.

or else he would not have fallen partly into the same errors Stoliczka committed on his first visit to that valley. Oldham gave the results of his reconnaissances in two papers[1]; subsequently I gave an outline of my own observations on the Spiti sections in a short paper.[2]

Stoliczka's sequence.

I have already given the sequence of formations in Spiti, according to Stoliczka, but it will be convenient to recapitulate the list.

He grouped the sedimentary formations below the jurassic "Spiti" shales into the following divisions:—

Upper Tagling		Lias.
Tagling limestone Pará do		Rhætic.
Lilang Series		Trias.
Kuling Series		Carboniferous.
Muth Series Babeh do.	Upper Lower	Silurian.

Trias.—I have little to say concerning the mesozoic rocks; of Spiti the general grouping as shown by Stoliczka is according to facts, and I have only to add that the trias (Muschelkalk horizon) does not rest directly upon carboniferous; but there is a series of beds, underlying the former conformably, ranging through the upper *Productus* shales (permian), the *Otoceras* (passage) beds and thin limestones with lower trias *Brachiopods*, which series comprises the lowest trias (Bunter) of Central Europe, but reaching down even to the upper permian. This series is not of great thickness, but is well exposed both at Muth, and in sections north of it (Kuling, &c.), but Stoliczka has apparently included it in the *Kuling beds.*

The chief changes which should now be made in the correlation and nomenclature of the Spiti formations concern the palæozoic group, but I shall give a summary of the points on which I differ chiefly with Stoliczka, at the end of this chapter.

Route taken by me.

I entered the Spiti drainage by the Babeh Pass (fig. 30), returning into the Sutlej valley by the Manirang Pass By doing so, I traversed the palæozoic and the

[1] Records XXI, pp 130 ff; *ib*, pp. 149 ff.
[2] Records XXII, 158 ff.

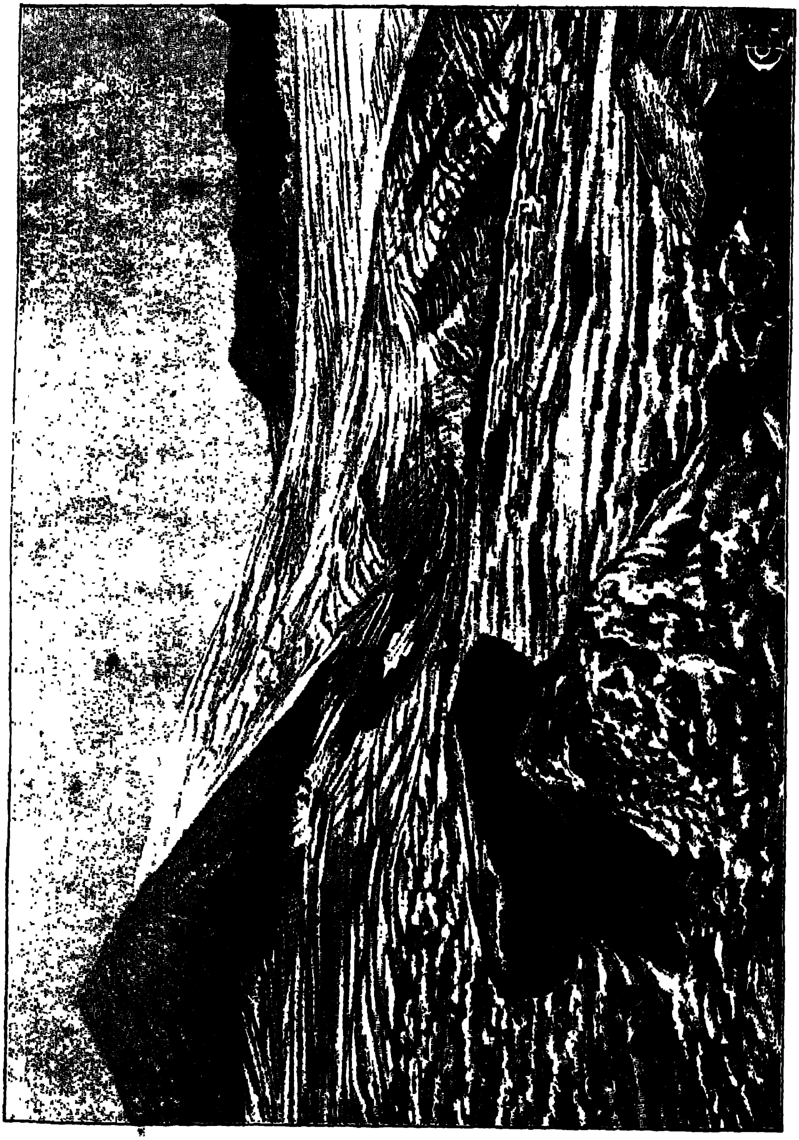

Fig. 30. Babeh glacier.

mesozoic groups, up to the upper rhætic system; it is an ascending section, and for the sake of convenience I will describe it in this order.

Babeh Pass.

The range over which the Babeh Pass leads (see map No. 2 and pl. 1) consists chiefly of crystalline rocks; thick-bedded gneiss (central gneiss of Stoliczka) associated with schists are the prevailing types of rock, but they are traversed by intrusive granite, and the boundary between the crystallines and the overlying sedimentary system is greatly obscured by masses of granite which have been wedged into that region. The boundary is therefore anything but clear at that point, especially as, in addition to the latter, much of the ground accessible to travellers is completely covered by snow and the ice masses of the Babeh glacier with its branches. The glacier is much cut up by crevasses and offers considerable difficulties in crossing later than July or August; but it is very probable that the granite will be found to enter the overlying formation much in the same manner as is seen in the sections north-east and east of Spiti.

Stoliczka believed that the slates (Babeh series) rest unconformably on the crystallines below; this does not seem to me to be the case; on the contrary, a gradual passage appears to exist and the general dip and strike being practically the same, I must conclude that here as in other sections the slate series is conformable to the metamorphics.

Háimanta system.

Babeh series, Stol. = Azoic, Strachey = Cambrian, Griesbach = and haimanta system.—Between the metamorphic rocks south of the Babeh Pass and the lower silurian exposed near Buldur (of the map), a strongly-developed system of rocks is seen, which I have identified with pre-silurian rocks of the Central Himálayas, called by General R. Strachey[1] *Azoic series.* The beds composing this system are conformably overlaid by the lower silurian; the general lithological sequence is almost identically the same as that of the haimantas in the sections further east, and the system may therefore safely be identified with the haimantas of

[1] Q. Journ. Geol. Soc., Vol. VII, p 292.

the Central Himálayas. The term "*Babeh*" system might have stood with some modification of its meaning, but as under that name some members of the silurian have also been included, I prefer to retain the term haimanta system.

This rock system consists, in the Spiti area, of a succession of chiefly quartzitic rocks; I did not study it in detail, but found similarly as in the Garhwál sections, a purple semi-metamorphic quartzite predominant. Associated with it are silicious shales, and a strongly developed conglomerate or rather boulder-bed which is a most characteristic rock, and is traceable from Spiti to the Nepál frontier. It is such a constant factor in this system, that once seen it will always easily be recognized. In its constancy it reminds me of the ever-recurring boulder-bed near the base of the Talchirs. These dark purplish quartzites and conglomerates form usually thick beds, and are associated with greenish talcose slates and semi-metamorphic schists which I found near the boundary of the gneissose series south of the Babeh Pass, and again near the upper boundary of the system. In these same greenish schists, fossil traces (*Bellerophon*?) were found in the Niti sections. Strata of thinner-bedded purple and brown silicious rocks are not absent, which also here show extensive and often very typical ripple-marking quite distinct from the wrinkling into which the beds have been contorted.

Extensive folding of strata.

The system shares in the extensive plication which has crumpled the entire succession of marine sedimentary rocks of this and the neighbouring sections of the Himálayas. The folds are generally very close, reserved flexures with their longer shoulders falling to the north and north-east.

Thickness of haimantas.

The thickness of the system I have not been able to ascertain, but it will probably be found to be not less than that of the haimantas of the north-eastern and eastern sections, where I estimate it as from 3,000 to 4,000 feet.

Buldur synclinal.

Near the camping-ground of Buldur (of the map), the beds form a deep synclinal, strike nearly east and west enclosing a portion of the silurian system

Conspicuous from afar, a band of bright red to purple silicious shale shows the deeply-bent curve of the synclinal, and at the same time forms the lower boundary of the silurians. The streams which join near this camping-ground from the south-west have eroded through the synclinal at nearly right angles and so exposed the structure. Dark limestone, and higher up flesh-coloured quartzites, are inclosed in this synclinal; they form respectively the lower and upper silurian, which, however, are seen much better lower down the Pin river valley.

Palæozoic section, south of Muth.

Between this synclinal and the village of Muth a perfect section of the palæozoic group may be studied. The structure is simple, though the entire sequence of beds is a good deal folded. Down in the valley along which the road passes, little or nothing is seen. The tract from the pass leads almost wholly over moraine matter, and over the enormous fans descending from the numerous small side ravines. The high and rugged ranges which enclose the valley have to be ascended before much of the true structure of the rocks can be made out. I think, on the whole, the range of hills forming the left side of the valley is perhaps the easier of the two, and enough of the beds forming it are exposed for the interpretation of the structure. I found it to consist entirely of palæozoic rocks, much crumpled; though, thanks to several very characteristic horizons, the structure is not difficult to unravel. The section, plate 1, illustrates the structure as actually seen along this range. Between Buldur and the Spiti river it is practically a natural profile in which I have left out the fans and numerous ravines.

The southern end of the range is formed by the haimantas as already described; they are conformably overlaid by the silurian system, which occupies the central portion of the range, followed, near its northern extension, south of Muth, by the devonian and carboniferous systems. The enormous sequence of formations between the base of the haimantas and the upper carboniferous quartzites near Muth shows one conformable whole; with great variations in lithological character of its component beds, but no *sharply*-defined boundaries

anywhere, rather unmistakable gradations from one into the other series of beds.

The first break occurs above the upper carboniferous, upon which the black "Kuling" shales, with many *Producti*, rest unconformably. This is the most important point connected with the structure of Spiti as will be seen later on.

Unconformity.

Sequence of palæozoic division.—The divisions of the palæozoic rocks of the Pin valley are therefore as follows:—

With trias-rhætic resting conformably on:—

9.	Black *Productus* (Kuling) shales	Permian.
	Unconformity	
8a	Dark flaggy limestone	Carboniferous.
8.	White quartzite series (Muth quartzite)	
7a.	Red *Crinoid* limestone	
7.	Earthy, dark-grey limestone	
6.	Hard, dark, concretionary *Coral* limestone with splintery shales	Devonian.
5	Dirty flesh-coloured to brown quartzites alternating with grey and greenish shales	Silurian.
4	*Coral*-limestone series	
3	Bright red quartz-shales	Haimantas.
2	Slate, quartzites and conglomerate series, seemingly conformable on:	
1.	Gneissose series.	

The divisions 1 to 5 correspond exactly with the silurian and pre-silurian sections of the Húndés and Central Himálayan ground. Fossils occur in nearly all the beds, but they are not very well preserved, and I did not devote much time to the search for them in Spiti. The rocks are so characteristic, and the lithological similarity to the eastern section is so complete, that I could pass on to the carboniferous rocks without hesitation.

The red quartz-shales (3) are as constant a termination to the haimantas as in Kumaun and Garhwál, and although the thickness is only from 200 to 300 feet, the bright red tint of the bed marks the boundary accurately.

Red quartz shales (3).

The overlying *Coral*-limestone (4) averages 300 feet in most sections, and consists principally of thin-bedded *Coral*-limestone of dark-grey colour, with

Coral-limestone (4).

occasional intercalations of silicious and shaly beds of greenish and pink colour. Near its junction with the red quartz-shales, beds of dark (fossiliferous) *Coral*-limestone alternate with the red shales, which are there often replaced by greenish-grey beds of otherwise similar lithological character. This alternation near its upper boundary would alone have induced me to include the quartz-shales (3) with the lower silurian, but the horizon seems more closely connected with the underlying quartzitic haimantas into which it passes gradually; so that I felt the red quartz-shales must rather be considered as structurally to belong to the underlying system In the *Coral*-limestone series (4) fossils are very common, though fine specimens are not easily got out. *Corals* and *Brachiopods* of lower silurian type are frequent.

Quartzite series (5).

This series passes upwards into the flesh-coloured quartzite series (5), which is ever present in all the upper silurian sections of the Central Himálayas. The thickness of it may here be from 1,500 to 2,000 feet, though I am inclined to think that it will be found to be rather below this estimate in less disturbed sections. Within these crushed flexures jointing, amounting often to considerable faulting, is so common, that a true estimate of thickness is not easy. The passage from the lower silurian *Coral*-limestone (4) into this series is gradual: beds of dirty greyish flesh-coloured quartzite make their appearance between the dark *Coral*-limestone low down in the latter series, increase in frequency higher up, until finally is developed as a distinct series which is roughly characterized as being an alternation of flesh-coloured to brown, often speckled quartzite and greyish-green shales with *fucoid* marks. The latter often show imperfect cleavage, and near the upper boundary increase in thickness. Fossils and casts of such are frequent throughout the formation; they are nearly all *Brachiopods; Orthis sp.* and *Corals* of upper silurian type are found throughout.

I believe that Dr. Stoliczka has rightly recognized this quartzitic series as silurian, fossils being common in it, especially on its weathered surfaces.

Descending the valley, he came up with the white quartzites near the village of Muth, which are further on overlaid by black "Kuling" shales; and I think he must have believed that it and the silurian quartzite belonged to one formation. But there is no silurian rock near Muth itself; and the white quartzite near that village is upper carboniferous, as will be seen further on.

Devonian limestone (6).

The upper silurian (5) is conformably overlaid by a thickness of from 700 to 800 feet of a very dark, hard limestone (6), concretionary in parts, alternating with dark, splintery shales. This series also has a wide geographical distribution, from the Nepál frontier in Byans, where it attains much greater thickness, to Spiti, little if at all varying in lithological character and containing few fossils. I found none in Spiti, and those met with in the eastern section might either be lowest carboniferous or devonian. Studying it connectedly with the adjoining horizons, its geological position at the base of the carboniferous is apparent; and then the uniform lithological character of the horizon over an extensive area is striking, but little could be gained by simple lithological identification in the field unaided by a clear view of its geotectonic conditions. Almost identically the same rock may be met with in higher horizons.

I think it is very probable that this same series extends far into Kashmír, as shown by Lydekker,[1] who places it into the carboniferous system. Lithologically similar rock occupies a carboniferous horizon in the Hindu Kúsh sections and in the prolongation of this mountain chain through north-western Áfghánistán and north-eastern Persia, where it probably thickens out and runs into upper carboniferous. I am induced to correlate it with devonian rather than carboniferous; the fossils found in it in the Central Himálayan sections, as far as I have been able to examine them up to this, might be characteristic of either devonian or lower carboniferous, but its evident connection through passage-beds and alternations of strata with the underlying upper silurians indicate that at all events between the upper portion

[1] Mem. Geol. Surv. Ind., Vol. XXII, 1883.

of the series (5) and the true carboniferous rocks (7 and 8) all intervening horizons from upper silurian to lower carboniferous must be included. Sharp boundaries there are none, and the whole represents an unbroken sequence of deposits.

Carboniferous.

The carboniferous system is much more fully represented in the Spiti area than in the sections eastwards. Not only are the several formations composing it represented in great thickness, but the sequence of horizons is more complete than is the case in Garhwál and Kumaun. The divisions of the system in Spiti are as shown on page 212; the limestone (8, a) is wanting in all the eastern sections,—eroded I believe before the black *Productus* shales were laid down on it. The lower boundary between this system and the underlying dark *Coral*-limestone (6) is not well defined.

Earthy grey *Crinoid* limestone (7).

The lowest horizon which I take to belong to the lower carboniferous is an earthy grey limestone (7) of irregular thickness and not very conspicuous. It might easily be altogether overlooked or considered part of the underlying *Coral*-limestone (6), if I had not observed it in the Dharma section more amply developed. Here, as there, it is characterized by the presence of *Crinoid* remains, which are found throughout this and the succeeding division. The passage from this grey limestone into

Red *Crinoid* limestones (7, a).

the overlying Red *Crinoid* limestone (7, a) is gradual, and the former seems altogether a local development only of the latter. Together, the two series may be from 600 to 800 feet in thickness. With the exception of badly-preserved *Orthoceras* fragments, nothing but *Crinoid* remains were found in this series; but the rock is so constant over the entire area of the Central Himálayas that a mistake is absolutely impossible. Its colour, a brownish-red (Indian red), distinguishes it everywhere, and often helped me in making out the structure of the upper palæozoics in mountain tracts which were only partially accessible to me. Its intense colouring, coupled with the fact that it is nearly invariably overlaid by the glaring white quartzite (8), serves as an unfailing

guide in such cases. Besides the red haimanta quartz-shales (3), it is the only red formation: a patchy red bed occurs in the rhætic and a semi-metamorphic red bed amongst the *Nummulitic* series, but with neither can the red *Crinoid* limestone be confounded.

White quartzite series (8).

It is overlaid by the white quartzite (8), the Muth quartzite of Stoliczka. This also is an old friend, met with in the Garhwál and Kumaun area, where I established its upper carboniferous age; it seems one of the most widely distributed of Himálayan formations, and Mr. Lydekker has shown that it also occurs in Kashmír near the base of the Kuling shales.[1]

The junction with the underlying Red *Crinoid* limestone is well defined, although several irregularly intercalated beds of the latter are found in the white quartzite near the boundary.

The main mass of the series is formed of fine-grained white quartzite in thick solid beds; in its upper portion the quartzite becomes occasionally a silicious sandstone, and there are now and then some thin limestone beds intercalated in the more eastern sections. Near Muth village in the Pin river valley the total thickness of it is about 500 feet. Some fossil traces, chiefly of *Brachiopods*, are found on the weathered surfaces of the rock, rarely in good preservation, and are indicative of the carboniferous age of the series.

Oldham has correctly correlated the Muth quartzite with the carboniferous white quartzite of Kashmir,[2] but he does not seem to have noticed the carboniferous beds which both underlie and overlie the formation.

Grey limestone series (8, a).

It is overlaid conformably by a hard, splintery grey limestone (8, a) in flaggy beds, of a total thickness of about 70 feet, which has yielded numerous fossils, though few in species. Amongst them are several *Producti*, *Athyris royssii* and *Corals*. Its evident connection with the white quartzite (8) and fossils define its upper carboniferous age.

The small ravine which descends near the village of Muth (see

[1] Mem Geol. Surv. Ind., Vol XXII. [2] Rec. XXI, p. 151-3.

Upper boundary of carboniferous. Permo-trias.

pl. 4) marks the upper boundary of the carboniferous system. The strata forming it are there seen to dip about 45° to 50° below the permo-trias, forming a great synclinal fold between Muth and Tilling which is splendidly exposed in the hill west of Khar (see pl. 5).

It will therefore be seen that the Spiti carboniferous, so far from being "*not well exposed*,"[1] is well represented and even more fully than in the sections eastwards. If I had only seen the sections in Spiti, where the beds of the permo-trias seem to rest conformably on the carboniferous, I would unhesitatingly have considered the small thickness of *Productus* shales (9) at the base of the lower trias also as carboniferous. But I have traced this contact from the frontier of Nepál, from Byans through the entire range of the Central Himálayas to Spiti, and found that whilst the *Productus* shales are never absent from the base of the trias, forming with it as it were one great system of beds, they overlap in succession the various horizons of the carboniferous system in the different areas. For instance, the permo-trias rests in Dharma and Byans on an eroded surface of white quartzite; in other sections on red *Crinoid* limestone in the Niti area; and here in Spiti on a limestone with carboniferous fossils not seen in the eastern sections. The inference therefore is that the permo-trias re-

Unconformity.

presents one continuous sequence which overlaps the several horizons of the carboniferous, and that the contact is unconformable. I can only again assert my conviction, strengthened by many observations all pointing to the same conclusions, that there are grounds for supposing that great physical changes have occurred in late carboniferous times, or at the beginning of the permian era I expressed this belief after my first examination of the Niti sections in 1879 in the paper above quoted.

The pl. 4, illustrates the beautiful cliff west of the village of Muth as viewed from the hills on the opposite side of the Pin river valley. A series of small ravines have scooped out part of the hill-range at

[1] Records, XXI, pp. 151-3

Muth itself, and in fact the village is built on the fan which issues from these ravines. It will be seen that a block of strata, which comprises the black *Productus* shales (9), the *Otoceras* beds (10), and the rest of the lower, middle and upper trias is inclosed conformably between carboniferous beds (7 and 8) and the rhætic which is strongly developed. There is no silurian within miles of the section,—not in fact till much further south. But between the dirty flesh-coloured upper silurians (5) and the *Crinoid* limestone (7) of the carboniferous, there is the strongly developed limestone system (6) intercalated, which I look upon as devonian. Stoliczka had evidently mistaken the white quartzite (8) of Muth for the quartzite (5) of the upper silurian, hence his mistake in believing that the carboniferous system was only poorly represented as a series of black shales with *Productus*,—the Kuling beds in fact, whereas the latter really only form the very uppermost beds of the palæozoics, underlying immediately the passage beds (10) with *Otoceras*.

Permo-trias near Muth.

Near Muth village, and on both sides of the valley, I found above the upper carboniferous limestone (8*a*) an unbroken succession of beds ranging from the permian *Productus* shales (9) to beds with *Terebratula gregaria* and *Rhynchonella austriaca* (upper rhætic) ; and, as I have already shown, this system of strata must be considered as being unconformable to those below. The trias with the permian *Productus* shales at their base overlap the entire series of the upper carboniferous in the Central Himálayas ; and I think therefore on stratigraphical grounds the division between the palæozoic group and the next following should, in the Himálayas, be made at the end of the upper carboniferous rather than the permian.

Permian Productus shales.

The permian *Productus* shales (10) are about 150 to 200 feet in thickness, mostly densely black, crumbling and soft, divided by strings of ferruginous concretions and layers of splintery shales. Occasionally an irregular bed of dark grey to olive-coloured sandstone, weathering dark brown, divides the formation and is generally full of fossils, chiefly *Producti*.

The shales also yielded many specimens of *Producti* and a few other *Brachiopods*.

These shales are evidently Stoliczka's typical Kuling beds. They are well exposed near Tilling, Khar and Kuling, and may easily be traced as a black band near the base of the hills north of Kuling. They again are visible in the Spiti river valley west of Dangkhar, below the wooden bridge above the junction with the Pin river. They yielded fossils wherever met, and are invariably passing upwards into beds, which Stoliczka failed to distinguish. These are dark limestone beds alternating with black friable shales, of about 200 feet in thickness and closely resembling the *Productus* shales below. But these beds have yielded, in all sections which I have hitherto examined, a fauna totally distinct from that found in the beds below. Numerous species of *Cephalopods*, chiefly of *Xenodiscus*, *Otoceras*, and a little higher up of *Ceratites*, may be picked up. *Producti* have disappeared, and in the uppermost beds of the series *Brachiopods* are found which I cannot distinguish from species found in the lowest trias of the Alps.

Otoceras stage.

Lowest trias horizon.

This succession of beds is well seen near Kuling, north-west of the village, where it is conformably overlaid by limestone with Muschelkalk species, followed by the remaining trias horizons.

Muschelkalk.

The beds with *Otoceras woodwardi* form a true passage-bed from the permian *Productus* shales into the lowest trias. Its exact homotaxis can now be established, for beds containing a fauna nearly related to the Himálayan one have been found in both Western Asia (Araxes) and in Sicily within the last few years. The fact of the disappearance of the *Producti*, and of the general habitus of the *Cephalopod* fauna reminding one of triassic horizons, have determined me to class the *Otoceras* zone—a passage stage—with the trias, while it may be probably correlated with the lowest formations of the Bunter; but there is really no sharply-defined boundary, no stratigraphical distinction

Otoceras stage (passage-beds).

between any division from the permian *Productus* beds (10) to the uppermost rhætic strata, the entire range of beds belonging to one unbroken system of deposits.

Sequence of trias and rhætic in Spiti.

There are strong points of resemblance between the trias-rhætic sections of Spiti and those of other parts of the Central Himálayas. Perhaps the only striking difference is this, that in Spiti the rhætic system is much ampler represented and its thickness much greater, although I have not been able to devote sufficient time to an accurate measurement of it. Very good sequences of beds of the two systems may be seen in the fine sections between Muth and Tilling, west of Khár, between the Spiti river and the Manirang pass, etc. Grouping these sections together I observed the following divisions of the trias-rhætic in descending order:—

17.	Bituminous, sometimes oolitic limestone of a few feet in thickness, with liassic fossils		Lias.
16	Limestone with many fossils; *Rhynch. austriaca*, *Cer gregaria*		Rhætic.
15.	*Lithodendron* limestone		
14.	Limestone with *Megalodon sp*; Dolomites: great thickness		
13.	Limestone and shales with fossils . .	Upper	Trias.
12.	*Daonella* limestone; great thickness .		
11.	Light-grey limestone; *Ptychites gerardi* other Muschelkalk forms . . . ; *Brachiopod* limestone . . .	Lower.	
10.	*Otoceras* beds (passage bed) . .		
9.	*Productus* shales		Permian.

Synclinal, north of Muth.

As I have already said, a great synclinal fold forms the belt between Muth and Tilling, followed by an anticlinal near the arch of which the village of Khar is situated. The ranges north of Khar to Dangkhar are a succession of more or less complicated flexures. The carboniferous rocks are therefore generally seen near the base of the ranges and in the valleys, whilst the higher cliffs are formed of the overlying permo-trias. But the best section of the carboniferous, which I have so far seen, is the one exposed along the jagged ridges of the chains of hills on both sides of the Pin valley and south of Muth. Marching north down the Pin river valley, I passed through the fine synclinal north

of Muth, which is cut through almost at right angles to the strike. East of Tilling a great mountain mass, almost entirely made up of the trias-rhætic group, and as the hillsides are absolutely devoid of any forest growth, the complicated folding comes out well in a photograph. Some two and a half miles further north, and north-west of Khar, a magnificent synclinal is seen (pl. 5.) ; in one profile almost the entire group of beds from the *Productus* shales (9) to upper rhætic is exposed. In the valley itself, as for instance in the low crags about Khar, the older trias and the carboniferous beds are exposed. Fossils abound both in the *Productus* shales (9) and the overlying *Otoceras* horizon (10). They contain numerous *Cephalopod* remains.

A mile and a half north-east of Khar is Kuling on the left side of the Pin river. This is Stoliczka's type section through the carboniferous system. But in point of fact only the uppermost part of the latter is in situ. Along the undercliff of the hill ranges which form the sides of the Pin river valley, one may observe here and there a few crags protruding from the mass of débris which skirt the cliffs ; these crags are found in places to consist of the white quartzite (8) of the upper carboniferous. The section generally shows great contortions (see profile pl. 1), but it is not difficult to find a densely black series of shales overlie the white quartzite here and there. It is well seen just north of the village of Kuling itself. These black shales are the *Productus* shales (9), and also here they yield in abundance the characteristic fossils. According to Stoliczka these shales are immediately followed by the middle trias with *Ptychites gerardi;* this is not the case. In the very section where this is supposed to be, close to Kuling, the *Productus* shales are overlaid conformably by an alternation of shales and dark limestone (10), the *Otóceras* stage of all the sections of the Central Himálayas. Also here at Kuling this stage yielded many of the characterstic fossils, mostly in fragments,—of *Otoceras woodwardi*, *Xenodiscus buchii*, &c., &c., just as it did in the Niti sections. Higher up I found this overlaid by an earthy limestone with *Brachiopods*, and then follow thick beds with decided Muschelkalk forms. The remainder of a very complete trias and rhætic section form the high hills which rise north-east of Kuling.

In the narrow valley of the lower Pin river greatly contorted (see section in pl. 1) sections of the trias and rhætic is seen and in the valley of the Spiti river itself just below the wooden bridge across the river, a fine anticlinal may be observed. Portions of carboniferous white quartzite (8) is brought up with associated hard grey limestone (8, a) and is overlaid by the dark *Productus* shales (9), which is followed by the remainder of the trias-rhætic group, above Dangkhár.

My chief object was attained when I successfully pieced together Stoliczka's surveys with my own, and I did not proceed to map the Spiti trias in detail. Proceeding down the Spiti river, I left the valley near the village Mani, and from there began the ascent of the Manirang pass, which leads all the way through beds of the trias and rhætic, wonderfully contorted. The latter, twisted into complicated folds, form the very saddle of the Manirang pass itself, see fig. 31.

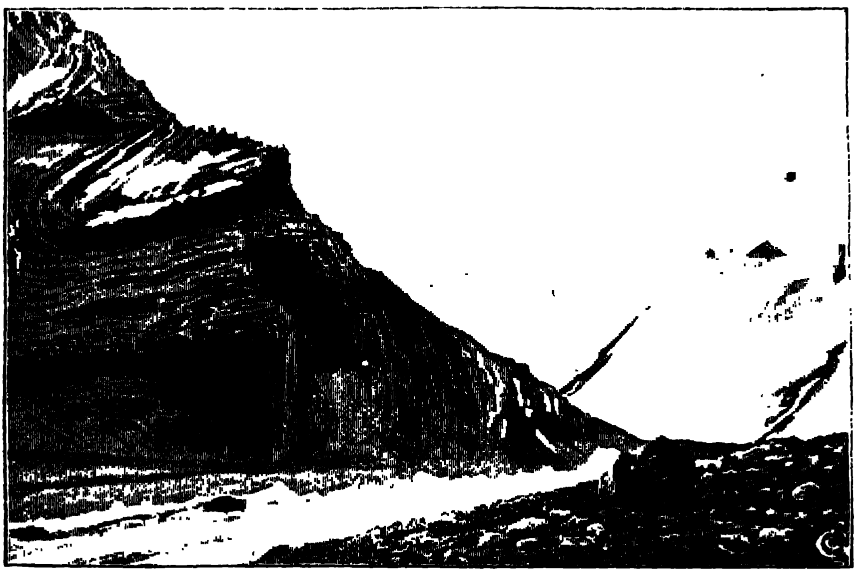

Fig. 31. Folded rhætic beds, top of Manirang pass.

A profile of the Spiti river anticlinal with flanking fixures will be seen in the last view of pl. i, which was taken east of Mani.

The descent from the Manirang pass to Pamachang into the

Thanam valley (Sutlej river drainage) leads over the entire palæozoic group down to the crystalline belt (here gneissose rocks). I found the palæozoics so much altered by great intrusions of granitic rock that I managed only with difficulty to recognize some, though not all, the divisions of it, seen elsewhere.

Points of difference with Stoliczka's correlations.

From the above sketch of the formations in Spiti, it appears that Stoliczka's views with regard to them must be modified in the following points:—

(1) The silurian closes with the flesh-coloured quartzite series (5) and not with the "Muth quartzite" (8), which is carboniferous; already correctly supposed by Oldham.

(2) The dark limestone (6) may be either lowest carboniferous or devonian; probably the latter.

(3) The carboniferous is in great force and reaches up into the fossiliferous limestone (8, a).

(4) The black *Productus* shales (9), the Kuling shales of Stoliczka belong structurally to the group of beds which ends with the rhætic and lias limestones, and they are probably of permian age.

(5) The middle trias (Muschelkalk) does not rest immediately on carboniferous as Stoliczka thought that it did; but at Muth at Kuling and other localities in Spiti it rests on beds with lower trias fossils, which again are linked through the *Otoceras* passage-beds with the permian *Productus* shales.

These are, in outline, the main points on which I differ from Stoliczka in the interpretation of the Spiti section. There are several minor differences which have been noticed in their proper places.

Having established a junction between my own work and Stoliczka's, I retraced my steps from the Sutlej valley to the plains of India, and thus brought to a close, but I hope for a short time only, my researches in the Central Himálayas.

CHAPTER VIII.—SUMMARY.

Limits of Himálayan area.

The Himálayan region forms part of the vast structure of the Central Asian elevation; it is so closely connected with the latter, both structurally and geographically, that it is very difficult to decide its exact limits. Native geographers and the Puranic scriptures define the Himálayas as comprising only the chain of snowy peaks at the head of the Ganges drainage. Modern views generally limit the Himálayas to the system of mountain ranges which extend between the Brahmaputra and Indus rivers. Of course, structurally, these ranges continue beyond these boundaries, but there are distinct changes in the features of the ranges which make these limits advisable. As regards the lateral extension of the region, several views have been formed; but I consider it most convenient, and at the same time more in accordance with the original significance of the term, to call Himálayas only the system of ranges which fringe the Tibetan highlands along its southern margin, a view which is now most generally held. That part of the system in which rise the headwaters of the Ganges drainage, and extending north-westwards as far as the Sutlej gorge, I call here the Central Himálayas, and within this area I divide the Central ranges into (1) Northern range (watershed), (and 2) Southern range (line of highest peaks).

Geological structure.

Whilst the Southern range of the Central Himálayas is formed chiefly of crystalline rocks, mostly gneissic with metamorphic schists, it is shown that the Northern range is almost entirely composed of a vast sequence of sedimentary strata, ranging from the lowest palæozoic to tertiary and recent age. The detailed description of these various formations I have given in the preceding pages, and I will here only recapitulate the following points.

Haimantas.

Immediately on the crystalline schists reposes an enormous thickness of beds of very varying lithological character, named haimantas by me, which are sharply

defined near its upper limit by most characteristic red quartz shales, which forms the base of the richly fossiliferous lower silurians. Structurally, this system is very much more fully developed than the succeeding silurians, being in most sections more than double the thickness of the latter. But the lower limit of the haimantas is obscure; an almost perfect lithological passage may be traced from the crystallines (vaikritas) into this system, both in the western and easternmost sections described.

One of the most characteristic amongst the various horizons in this system is a great thickness of a coarse conglomerate or boulder-bed, which in some sections alternates with slaty beds, but is never entirely absent. This, in conjunction with the ripple-marking which may be seen on nearly all the slaty beds of the haimantas, indicates clearly that we must suppose the ancient coast-limits of haimanta age to have been in close proximity. The apparent overlap of haimantas on gneiss (Niti area) is easily explained, if we suppose this system to have been developed in this region as a littoral formation. It is extremely probable that one of the earliest Himálayan disturbances occurred immediately before haimanta times.

Lithological resemblance, not less than structural features, point to the probability that a part at least of the slate series of the Lower Himálayas are equivalents of the haimanta system of the Central Himálayas. I believe even that some of the older rocks, which immediately underlie the Vindhian group, may yet be found to belong to the same age. It would thus follow that the haimanta seas had extended not only over the greater part of the present Himálayan area, but perhaps also as far south as Central India. If so, the line of the Central Himálayas was probably marked out as a chain of elevations, from the waste of which the boulders and pebbles of the haimanta conglomerate and of the Simla rocks were derived. The latter supposition is also advanced by the authors of the "Manual."[1]

[1] Page 679.

Palæozoic group.

The palæozoic group forms an uninterrupted sequence from the lowest haimantas to the upper carboniferous; and this sequence is the same, or nearly so, in all the sections of the Central Himálayas. The first indications of a disturbance are noticeable in the upper carboniferous. Certain beds of the latter are wanting in some sections, and I found the next following system overlapping what I must look upon as an eroded surface of upper carboniferous.

Permian to lower lias.

Nearly everywhere I found the latter overlaid by a great sequence of beds, which represent permian, trias, rhætic and lias. This group of systems forms an uninterrupted sequence, with conformable bedding throughout. The base of the sequence is everywhere seen to be dark crumbling shales, which contain a palæozoic fauna, probably permian in character, which gradually passes into lowest trias beds through dark limestones and shales which has yielded a curious fauna, some of the species of which have strong affinities with permian forms. On it rest lower trias beds, followed by a continuous succession of strata, which reach up into the lower lias.

The same condition prevails in Spiti, where the lower lias is also well represented.

Jurassic Spiti shales. Cretaceous.

The lias limestones and shales are overlaid by jurassic (Spiti) beds, which have yielded a large number of fossils, but which have not yet been entirely examined. Most of them appear to belong to the upper jurassics rather than middle or lower. Whether the latter is represented or not, is not quite clear, but the bedding of the Spiti shales is isoclinal with the lower lias, and if there is an unconformity between these systems, it may only be conjectured from the sudden and entire change in lithological character of the two formations, coupled with the absence of lower jurassic forms amongst the species found in the Spiti shales.

From this formation there is a gradual passage into the greenish shales and sandstones of the cretaceous (with perhaps upper jurassic),

the Gieumal sandstone of Stoliczka. Again a sudden change in lithological character from these sandstones into the white limestone of the upper cretaceous seems to point to the probability of there having occurred physical changes on a large scale after the deposition of the lower cretaceous. In the Central Asian area, and also in the Perso-Afghán region, a strongly marked overlap of the upper cretaceous over the neocomian limestones may be observed.

Probably similar features will be found to exist in the Himálayan area the cretaceous rocks of which have not been closely studied.

Tertiaries.

The tertiary system is fully developed, though few fossils were found in it. A great unconformity occurs between certain sandstones which cannot be older than upper eocene (overlying *nummulitics*) and are probably of miocene age and horizontal beds of clay, sand, gravels and sandstone, which form the high table-land of Húndés, which, having yielded mammalian bone remains, are commonly known as the ossiferous beds of Húndés.

Periodical disturbances.

From the foregoing it will be seen that special disturbances must have occurred in early geological times and have been repeated periodically.

It is very certain that near the beginning of the haimanta era sufficient physical changes have occurred not only to completely alter the lithological character of the deposits in course of formation, but also the area in which the latter were laid down. The great thicknesses of coarse conglomerates, which are of widespread extent in the lower haimantas, indicate the nearness of land at the time or as I may term it the existence of an early region of elevation in place of the present area of the Central Himálayas. At the same time lithological, not less than structural, conditions point to the probability of true haimanta deposits having been laid down also on the south slope of what is now the Central Himálayan region.

The compression of the Himálayan—and indeed entire Central Asian area and consequent folding, and thus elevating of it, most probably went on uninterruptedly and continuously from the earliest

epochs to the present; indeed, the natural forces exerted on the surface of our globe condition this. But in addition to this, periodical greater changes have taken place and are proved by the sections of the Central Himálayas.

After the lower haimanta recession of deposits from the entire Himálayan area into well-defined northern and southern regions of formations, we find an undisturbed sequence of beds till the upper carboniferous, when clear evidences of a great overlap may be observed. This is well marked in the Central Himálayas and is clearly proved in the Perso Afghán area, where carboniferous marine limestones are followed by littoral deposits, the upper beds of which contain a triassic fauna. Here we have therefore a period of subaerial and marine erosion of the carboniferous followed by an overlap of probably a permian and triassic sequence of deposits.

The third period of disturbance seems to belong to the lower jurassic age, where a gap (partial or otherwise) between lower lias and middle or upper jurassics is probable.

I may mention that this gap is not observable in the Perso-Afghán region, where the passage from the trias into jurassics and neocomian is gradual.

On the other hand, a decided overlap on an immense scale has occurred in later cretaceous times in Central Asia, and we find that hippuritic limestone covers both jurassics and neocomian unconformably. Such is less apparent in the Central Himálayas, though probable enough when considering the sudden change from the sandstone and shales of the lower cretaceous to the hard, white and grey limestone of the upper cretaceous.

The fifth period of disturbance which is clearly shown in the Central Himálayas occurred after the deposition of the sandstones which overlie the *nummulitics* of Húndés and which are probably of miocene age. A considerable gap seems to exist between the latter and the ossiferous younger tertiaries which fill the Húndés basin.

There is clear evidence therefore of very early disturbances having taken place in the Himálayan area. There are abundant proofs that

minor changes in the distribution of land and water have occurred not only frequently, but we can scarcely believe otherwise than that the forces which have resulted in the intricate folding and crumpling of the great sequence of sedimentary and crystalline strata must have been of very long duration, and were probably existent from the very earliest date when the first grain of sediment was deposited in the Himálayan seas. We can go further. Whatever other—and as yet only dimly understood—forces were at work to produce this contraction and folding of the earth's crust, we know of two forces about which there can scarcely be the slightest doubt. The first is the gradual cooling of our earth, and consequent lessening and shrinking of the surface of it. Secondly—and this is a force which may be mathematically expressed—we know that the centrifugal force endeavours to move every point on the surface of the earth in a direction opposite to that in which gravitation attracts it.

The actual force exerted is the resultant between the centrifugal and tangential forces, and it has the tendency, if I may so express it, of gradually moving each point on the surface of the earth towards the equator. It may be supposed that an enormous sequence, of to a certain extent pliable deposits, trying to move bodily, as it were, towards the equator, but *en route* arrested and banked up against a rigid mass of which the peninsula of India is a small remnant only, must necessarily have suffered wrinkling, and lateral crushing.

These forces operated since the earth existed and must be active now. But throughout the great sequence of the palæozoic, mesozoic and kainozoic deposits we search in vain for an internal explanation of the great unconformities and disturbances of coast-line which have taken place at certain intervals, such as I have sketched out above. That these changes were not local overlaps only is apparent when we compare the Central Himálayan area with the Perso-Afghán region. In the latter the physical changes are far more clearly marked. At the close of the carboniferous epoch, which was one of pelagic conditions in the Hindu Kúsh area, Khorassán and Persia, the distribution of land and water must have considerably changed, as we find imme-

diately above the carboniferous limestone, shaly beds with coal-seams and conglomerates and partly littoral, partly fresh-water conditions prevailed in that area till late into jurassic times. These disturbances which are slightly indicated in the Himálayas are clearly shown and occur on a larger scale in the West Central Asian area.

The next great change in the Perso-Áfghán area is the great overlap of the upper cretaceous (hippuritic) limestone over the neocomian, already alluded to. It has resulted in a great and often strongly expressed unconformity. Again another and strongly marked change occurs in the middle tertiaries of the Perso-Áfghán area. The purely marine miocene beds are overlaid, often with isoclinal bedding, at other localities distinctly unconformably, by upper tertiary freshwater deposits. If the folding and crushing process were alone the cause of these—shall I call them cycles of disturbances—then at least some evidence of it should be observable within the sequences of rocks as we see them.

On the other hand, there is no direct evidence to show that the raising of the Himálayas as a mountain system was in any way due to these periodical fluctuations of sea-level, or as Suess terms it, the "positive" and "negative" movements of the liquid covering of the earth. The evidence of the transverse valleys in the Himálayas points even to the probability that the raising up of the chains of hills forming them, *i.e.*, the folding and crumpling of its rock strata, must have kept pace, step for step, with the erosion by rivers which we now find traversing the whole width of this mountain system.

Such transverse valleys, however, can only date since the last of the periodical changes spoken of, *i.e.*, since the middle tertiary epoch. Before that time, up to the point when the last marine tertiary deposits were laid down along the margin of the Himálayas, the relative position of the Peninsular India and Central Asia must have been the reverse of what we know them to be now, that is to say, the surface of the Central Asian elevated massif must have been nearer the centre of our earth than the surface of the continent, of which the Peninsula of India forms only a portion of the remains.

It is improbable that the folding action alone has been the cause of the present structure and orographical features of Central Asia and the areas south of it; for the final great changes which have resulted in the draining of Central Asia of the tertiary seas, of which nothing now remains but isolated salt-water lake-basins, such as the Aral and the Caspián are, we must look for other causes.

Possibly such may be found in the sinking in of large portions of the southern hemisphere which caused the submergence of the Indo-African area below what is now the Indian Ocean. With it the part, now known to us as the Peninsula of India may have partially broken down, though of that we have no direct evidence, unless the improbability that the Central Asian area could have been pushed up to its present elevation above the Peninsula entirely through being folded might be adduced as proof. Large tracts of Central Asia we know could never have suffered folding to any but very slight extent, as, for instance, the greater part of the tertiaries of the Turkistán region which are often in undisturbed horizontal position. On the other hand, these latter are but little raised above—some are even depressed below—the level of India.

In all these considerations and speculations two points seem probable almost beyond doubt, namely: First, that the last and main disturbance of physical conditions of the Central Asian area has taken place in post eocene, perhaps in middle tertiary times, and is most likely still continued to the present day.[1] Secondly, that this period of disturbance coincides with the sinking in of the Indo-African continent, which "breaking down" caused the final draining of the tertiary seas from the Central Asian area.

Not so certain is whether the raising *en bloc* of the Central Asian mass above the level of the Indian Peninsula is due only to the folding process, or whether some movement downwards of the Peninsula, in connection with the sinking in of the Indo-African region, may not have had a share in producing the present configuration of the

[1] Manual, pp. lvi, 689, &c.

Húndés plateau. Some such movement may be conjectured. Certain supposed elevations of the Peninsula may possibly be owing to "negative" movements of the area of the Indian Ocean, in other words, to the sinking in of the ocean bed.[1]

[1] *See* "Manual," p. 681.

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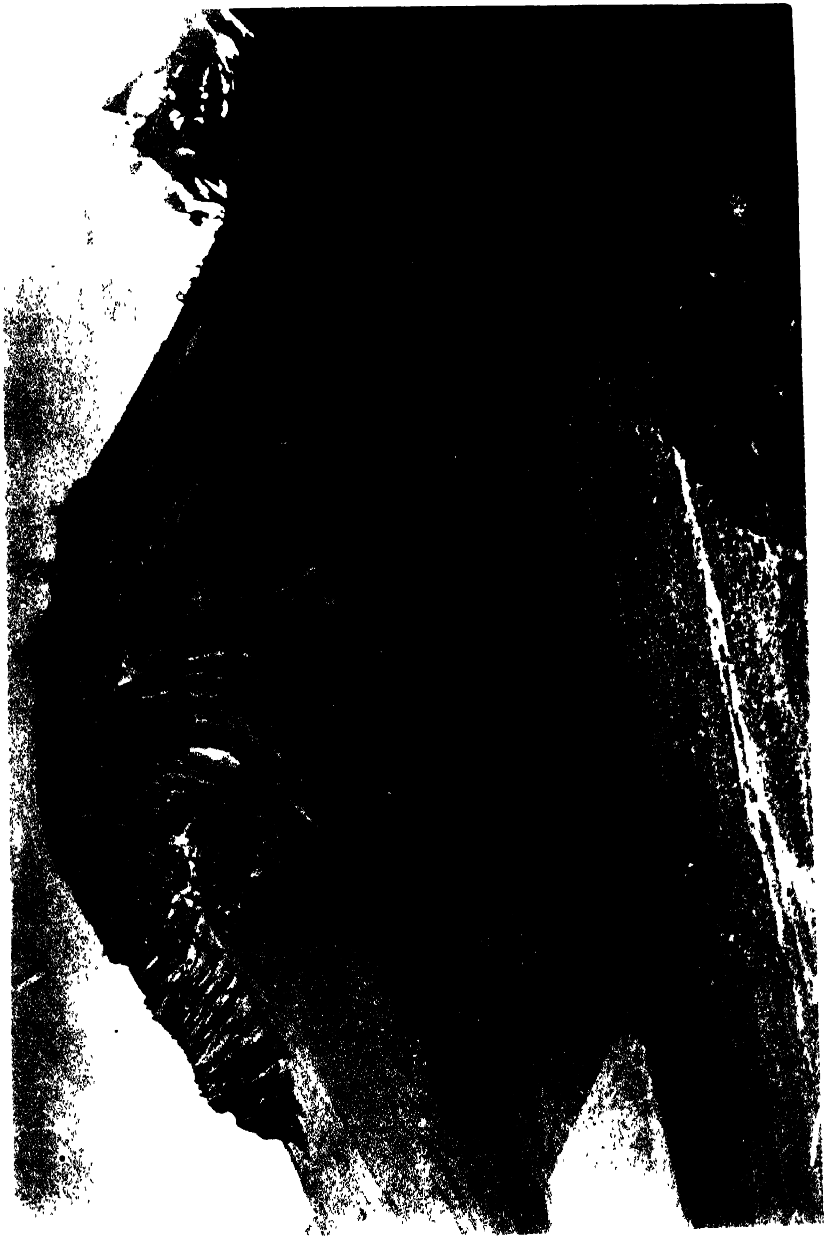


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